VOL. 17, NO. 7 • JULY 1961

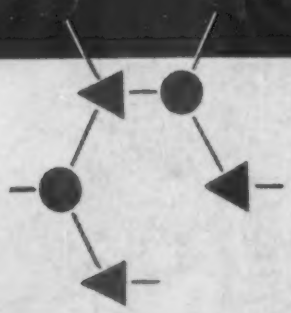
SPE JOURNAL

The Official Publication of the Society of Plastics Engineers, Inc.

EDITORIAL DEPT.
UNIVERSITY MICROFILMS, INC.
313 N. FIRST ST.
ANN ARBOR, MICH.

plastics in automobiles - 645

polymer degradation - 665



SPE goals half-way mark - 692

ROYLE

SPIROD®

EXTRUDERS

Serve In Laboratories
As Production Prototypes

Many plastic compound suppliers use highly instrumented Royle Spirod Extruders in their technical and research laboratories. These extruders are fully equipped with the latest temperature control mechanisms — including pressure and temperature sensing instruments.

These suppliers have chosen Royle because Royle Spirod Extruders are easily adaptable to the installation of compound melt sensing instruments at any point along the barrel. With them are used special panels which indicate and record all data received. Royle Extruders are capable of holding barrel temperatures to ±1° with the newly designed control panels and instruments.

Whether your needs are for a specially designed laboratory installation or a high-production standard unit, you, too, can reap the advantages of Royle experience. Call Royle today and ask for a sales engineer to recommend an extruder suited to your application.

Royle maintains a Sales Service Laboratory for users of Royle Extruding Equipment. Here Royle engineers assist in making simulated production runs as well as in operator training and developing process techniques. Also available is field assistance for installation, start-up and any ensuing production problems which may occur.

Send for bulletins on production extruders 2½" through 12".

As they have since 1880,
Royle is first in Extruder development.

ROYLE
Paterson, N. J.

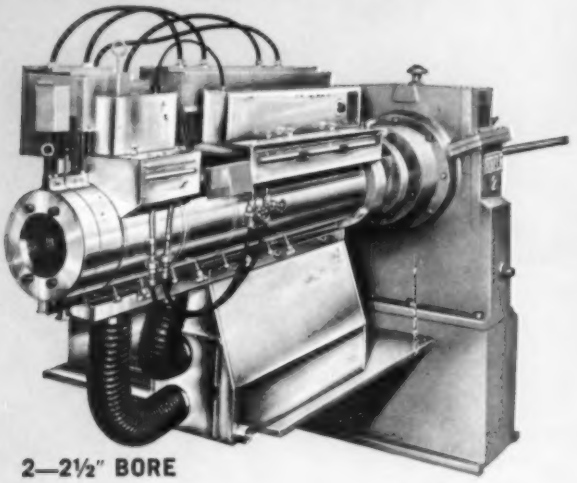
JOHN ROYLE & SONS

Pioneered the Continuous Extrusion Process in 1880

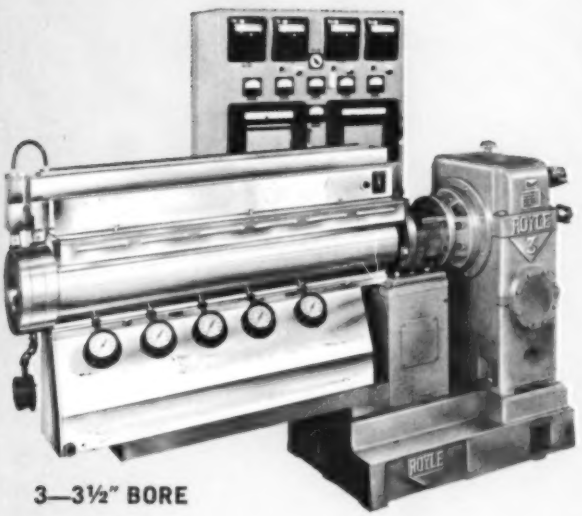
8 Essex Street, Paterson 3, New Jersey

Tudor Road, Wealdstone, Middlesex, England, James Day (Machinery) Ltd., Harrow 2655-6. **Home Office,** V. M. Hovey, J. W. VanRiper, SHerwood 2-8262. **Akron, Ohio,** J. C. Clinefelter Co., Blackstone 3-9222. **Downey, Cal.,** H. M. Royal, Inc., TOpaz 1-0371. **Tokyo, Japan,** Okura Trading Company, Ltd., (56) 2130-2149.

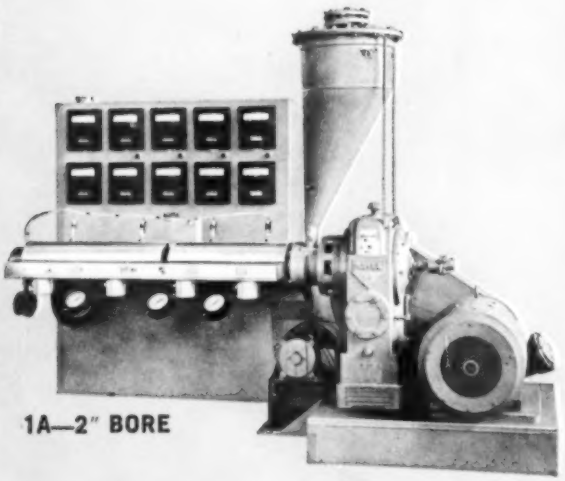
Royle Spirod extruders designed for Technical Service Laboratories



2—2½" BORE



3—3½" BORE



1A—2" BORE

DOWN!

COMES THE PRICE OF PFIZER ITACONIC ACID AND ESTERS

Pfizer brings the price of Itaconic Acid (technical grade) down to 34.5¢/lb.*, and reduces Itaconic Acid (refined grade), Dimethyl Itaconate and Dibutyl Itaconate to 39.5¢/lb.* ■ Now these highly efficient monomers can be economically used for an ever-widening range of industrial applications. For example: ■ Itaconic Acid, with its unique structure—a beta-carboxyl group separated from the polymer chain by a methylene group—imparts specific adhesion to selected substrates and improves emulsion stability. ■ Dimethyl Itaconate is of particular interest as a comonomer for improving heat distortion temperatures, toughness and weathering in molding compounds. Both Dimethyl and Dibutyl Itaconate are effective comonomers for improving the weathering characteristics of protective coatings. ■ Write today for full details on the new low prices and the growing uses for the Pfizer family of Itaconates.

CHAS. PFIZER & CO., INC., Chemical Division, Brooklyn 6, N.Y.

*Carload quantities f.o.b. our plants. Less-than-carload prices also down. Investigate!

Science for the world's well being
Pfizer
CHEMICAL DIVISION
Industrial Chemical Development Dept.

How to control your temperature...

Your personal temperature may soar when you see the advantages that others gain by improving control of temperature in operations like yours. But you can confidently control both types of temperature by using our consulting service and, if necessary, some of our instruments.

For we are specialists in temperature control. Our world-wide field force is constantly working with situations like yours, seeking waste and hidden potentials where "control is no problem." Working with your own people, chances are they'll find ways to boost your production...assure quality... reduce costs.

We provide such service without charge, to determine whether you really need our indicators or controllers or recorders, thermocouples and accessories. Chances are that you do; for our instruments soon save their cost in avoiding work-stoppage and reducing maintenance.

Proportioning Controller

Gardsman Model JP (shown) automatically adjusts On-time to Off-time to maintain any desired temperature within extremely close limits. Wide selection of Gardsman controllers provides for all control applications. All are tubeless, "solid-state" and proved in wide use. Phone your West consultant (see Yellow pages) or write Chicago office for Bulletin JP or for COM digest-catalog of line.

WEST Instrument CORPORATION
SALES OFFICES IN PRINCIPAL CITIES
FACTORY AND GENERAL OFFICES:
4359B W. MONTROSE, CHICAGO 41, ILL.
BRITISH SUBSIDIARY:
WEST INSTRUMENT, LTD.
52 Regent St., Brighton 1, Sussex

the trend is to **WEST**

Society of Plastics Engineers, Inc.

An international scientific and educational organization of more than 9,000 individual members devoted to the development and dissemination of technical information in the fields of research, design, development, production and utilization of plastics materials and products. The Society is incorporated under the laws of the State of Michigan.

Executive and Business Offices
65 Prospect St.
Stamford, Conn.

Officers of the Society

Frank W. Reynolds, *President*
James R. Lampman, *Vice President, Eng.*
John Delmonte, *Vice President, Adm.*
Maurice F. Malone, *Secretary*
John N. Derutich, *Treasurer*
Thomas A. Bissell, *Executive Secretary*

All correspondence relative to business matters, meetings of the Society, membership, advertising etc., should be addressed to the business offices listed above.

●

Members should notify the business offices at least 30 days in advance of contemplated changes in address.

●

Membership in the Society is available to qualified individuals. Inquiries should be addressed to the business office.

●

Membership in the Society is extended to individuals who by previous training or experience or by present occupation qualify them to carry out the objective of the Society. The privileges of membership are designed to enhance the professional standing of the individual member by encouraging participation in scientific and technical programs and professional activities; by developing close personal contacts and acquaintanceship among members; and by providing an opportunity to administer the local and national activities of the Society.

●

Neither the Society of Plastics Engineers, Inc., nor the SPE Journal is responsible for the views expressed by individual contributors either in articles published in the Journal or in technical papers presented at meetings of the Society.

Non-Member Subscription Rates

*DOMESTIC		**FOREIGN	
1 Year	$ 8.00	1 Year	$15.00
2 Years	14.00	2 Years	24.00
3 Years	20.00	3 Years	30.00

**Single Issue $1.65 **Single Issue $2.00 and single copies of the Roster Issue at $10.00.*

• The SPE Journal is Published at 215 Canal St., Manchester, N. H. Address changes, undeliverable copies and orders for subscriptions should be sent to 65 Prospect St., Stamford, Conn.

SPE JOURNAL
VOL. 17 • NO. 7
JULY 1961

COVER:
Directory to three stories—
- **Polymer Degradation**
- **Plastics in Automobiles**
- **SPE Goals—The Halfway Mark**

SPE Journal Newsletter 637

REGIONAL TECHNICAL CONFERENCE
Plastics for Tooling, Sept. 12, 1961 sponsored by the Central Indiana Section
New Developments in Plastic Tooling 642

Special Feature

Plastics for the Automotive Industry
Staff condensation of Detroit RETEC Papers
Plastics application in the automotive industry is analyzed 645

SPE Journal Features

Speaking of Extrusion—Trouble Shooting in Blow Molding
H. S. Malby, A. N. Ciarlone, C. M. Greene, Celanese Polymer Co.
Suggestions for elimination of production problems in blow molding 653

Moldmaking—The New Mold, Its Problems and Some Solutions
John A. Kavanagh, Standard Tool Co.
Proper evaluation of mold design parameters results in more efficient production 661

Polymer Science—Thermal degradation of Organic Polymers
Samuel L. Madorsky, National Bureau of Standards, Washington 25, D. C.
More usage of polymers at higher temperatures prompts study of degradation mechanisms 665

Technical Articles

Cured Phenolic Resins Plasticized by Substituents on the Aromatic Ring
J. H. Freeman and Edward J. Traynor, Westinghouse Research Laboratories
Superior plasticizing properties induced by integral alkyl substitutes 673

New Crosslinkers for Furfuryl Alcohol Resins
Erik R. Nielsen, Armour Research Foundation
Flexible, high quality furfuryl alcohol, resins made with new crosslinking process 678

Hydraulics on Plastic Injection Molding Machines
R. H. Mezger, Vickers Inc.
Know your hydraulic system, its function, maintenance and design 680

Plastics Used in Electrical Appliances
I. M. Kline, Underwriters' Laboratories Inc.
Standards necessary for plastics in appliance applications 681

Microdispersed Formaldehyde-Arene Resins
J. E. Goodrich, California Research Corp.
Cheap raw materials and an emulsification technique produce a thermally stable microdispersed product 683

News of SPE

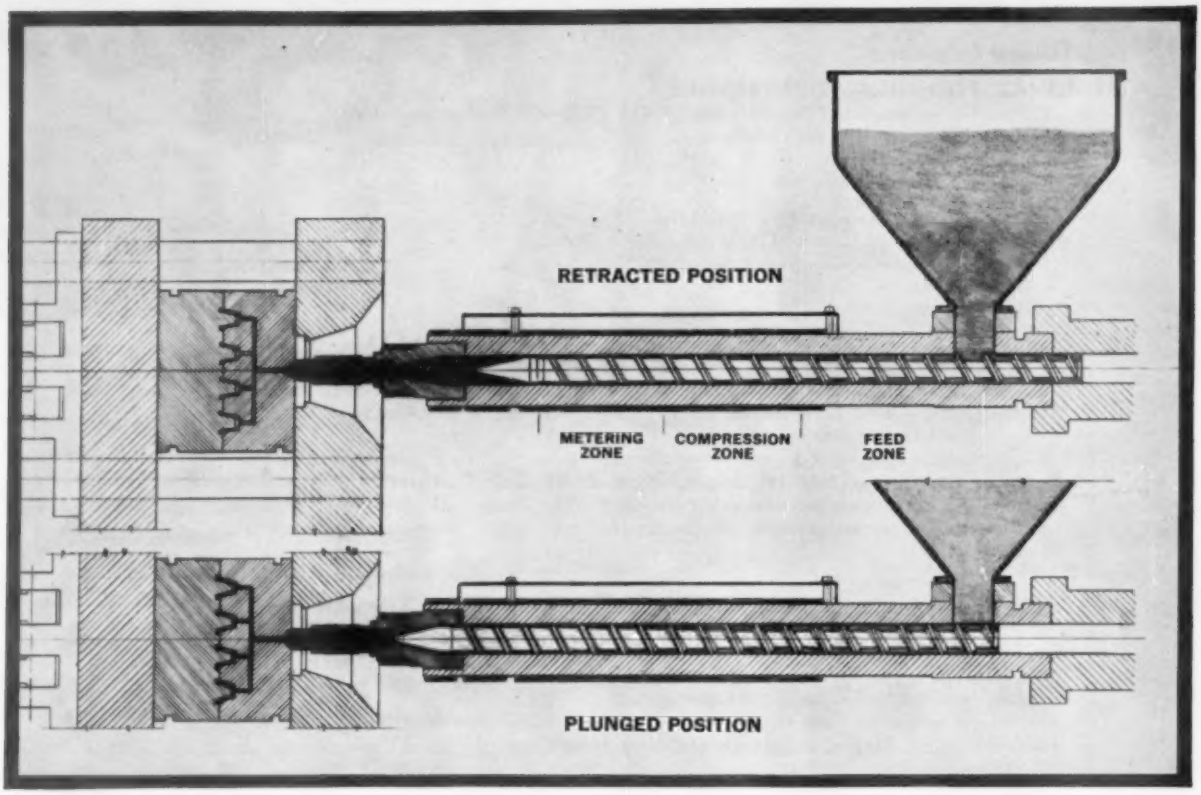
PAG Progress—Thermosetting Molding PAG Continues to Expand Activities and Membership
Ross H. Dean, Chairman, Thermosetting Molding PAG, (Sterling Inc.) 690

Society Action—Mid-Year Progress Report
Frank W. Reynolds, SPE President, (International Business Machine Corp.) 692

Departments

Editorial 629
Letters to the Editor 633
Book Reviews 693
Section News 695
About Members 698
Plastics Around the World 701
New Equipment and Material 702
Employment and Service Guide 703
Advertisers' Index 704

NOW! RECIPROCATING SCREW INJECTION FOR THE REED "BUILDING BLOCK" LINE



Here's another REED engineering development added to the new "Building Block" line . . . a single reciprocating screw that plasticizes and injects all thermoplastic materials. This unit is available in capacities up to 36 oz. as an integral part of any injection molding machine you specify in the exclusive REED "Building Block" group.

With this reciprocating screw, you can expect:

• Good color blending on dry mix • Good material and color changes • More effective injection pressures • Better homogeneity of the melt • Less orientation of plasticized material, giving stronger finished parts.

Ask your Reed-Prentice Sales Engineer for full details on this new reciprocating screw injection. He will be glad to show you how it fits into the new "Building Block" line, and how you can specify the machine that best meets your needs from the 16 different combinations of link and injection ends that only REED offers.

REED-PRENTICE division of PACKAGE MACHINERY COMPANY
EAST LONGMEADOW, MASSACHUSETTS

BRANCH OFFICES: NEW YORK • CHICAGO • BUFFALO • CLEVELAND • DEARBORN • KANSAS CITY • LOS ANGELES

Uniform quality of Enjay MEK starts here

You benefit from the careful, painstaking controls at Enjay which start when the crude leaves the ground and do not end until the finished chemical is delivered to your plant. Enjay methyl ethyl ketone comes to you *only* after it has passed strict specification tests using modern test methods, including gas chromatography. You'll find our specs among the highest in the industry:

Purity (wt per cent) min.	99.3
Specific Gravity (20/20°C) min.	0.805
max.	0.807
Acidity (as acetic acid—wt per cent) max.	0.002
Color (Hazen) max.	10.0
Non-volatile Matter (mg/100 ml) max.	2.0
Distillation °C	
Initial min.	78.7
Dry Point max.	80.7
Water (wt per cent)	0.2
Residual Odor	None
Appearance	Clear and free of suspended matter

Users of Enjay MEK are assured of dependable supply from modern facilities; rapid delivery from strategically located supply points; and technical service that is unsurpassed in the industry. Let us show you how these assets can make a difference to you. Write to Enjay, 15 West 51st Street, New York 19, New York.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

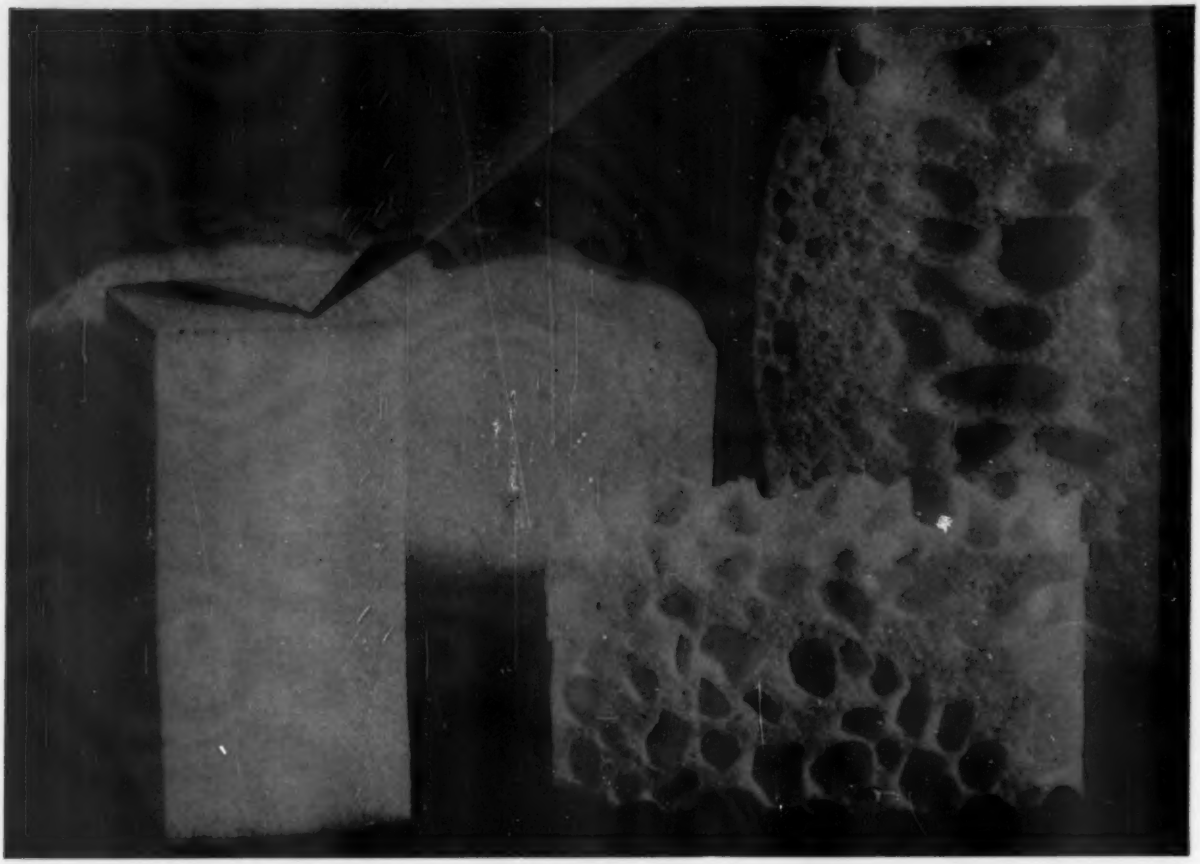
ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY
CHEMICALS

SILICONE NEWS from Dow Corning

Better Foam, Better Profits



New Silicones Assure Production Of Top Quality Polyurethane Foams

Whether you make prepolymer or one-shot polyurethane foam — rigid or flexible — there's a Dow Corning silicone additive to help you produce uniform foam consistently. These silicone additives take the guesswork out of production. They show no variation from lot to lot and perform exactly the same, time after time to help you step up production efficiency . . . build up repeat sales and improve profits.

Ease of handling is another benefit you get with a Dow Corning silicone additive. Other worthwhile features are lower foam density, better foam stability, and lower costs through effectiveness at lower concentrations.

Dow Corning's leading specialty is research and development in the field of silicone chemistry. That's why our chemists are able to provide you with the newest technical information about the use of silicones in polyurethanes . . . to provide you with new and better materials like Dow Corning 199, the silicone-glycol copolymer for flexible, one-shot polyurethane foam and for rigid, prepolymer foam.

For more information about silicone additives for polyurethane foams, phone the Dow Corning office nearest you or write Dept. 1619.

Free, new brochure—
"How Silicones Work for the CPI"
Write Dept. 1619.

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D. C.

SPE JOURNAL

Editor
MELVYN A. KOHUDIC

Editor Emeritus
DR. JESSE H. DAY

Technical Editor
LOUIS NATURMAN

Layout and Production
LEE COOPER

Editorial Assistant
HELEN B. TIEDEMANN

Feature Editors

Molding Cycles
Milton A. Sanders

Standards for Plastics
Dr. Frank W. Reinhart

Moldmaking
John A. Kavanagh

Polymer Science
Dr. Irvin Wolock

Reinforced Plastics
George Lubin

Society Action
Thomas A. Bissell

Speaking of Extrusion
B. H. Maddock

PAG Progress
Saul Gobstein

SPE Publications Committee

Dr. Alex Sacher, *Chmn.*
Dr. Raymond F. Boyer
Dr. Jesse H. Day
Dr. Herman F. Mark
Frank A. Martin
Eugene C. Quear
Dr. Frank W. Reinhart
Irvin I. Rubin
Dr. Sidney J. Stein
Parke Woodworth

Editorial Advisory Board

Dr. Frank W. Reinhart, *Chmn.*
Robert W. Barber
Dr. Luther Bolstad
Edward F. Borro, Sr.
Benjamin S. Collins
William Croll
Edward J. Fitzpatrick
Russell M. Houghton
Dr. Herman S. Kaufman
John P. Lombardi
Thomas F. McLaughlin
Robert E. Monica
Jules Pinsky
Robert D. Sackett
Edward W. Vaill
Dr. Edward G. Bobalek
Dr. Robert L. Patrick
Lawrence M. Debing
John B. Howard
Dr. Bryce Maxwell
Dr. Frederick J. McGarry
Dr. Robert B. Mesrobian

Circulation Manager
LEWIS A. BERNHARD

Advertising Manager
LEON R. NOE

Managing Assistant
JANE W. LAZARUS

Advertising Representatives

Eastern
S. Patrick Johnson
65 Prospect Street
Stamford, Conn.
Fireside 8-7528

Upper Midwest
M. B. Bock & Assoc.
634—Baker Bldg.
Minneapolis 2, Minn.
FEderal 6-5357

Ohio-Eastern Michigan and Western Pennsylvania
Raymond B. Mooney & Associates
6032 Graystone Drive
Sylvania, Ohio
TUrner 2-6385
and
18360 James Couzens Highway
Detroit 35, Mich.
Diamond 1-7424

West Coast
Thomas & Clark Co.
681 Market St.
San Francisco 5, Calif.
DOuglas 2-8547
and
6000 Sunset Blvd.,
Rm. 202
Hollywood 28, Calif.
HOllywood 3-4111

Ohio-Kentucky
Donald J. Catron
129 Harmony Lane
Toledo, Ohio
JEfferson 6-3177

Central-Midwest
R. D. Henriquez
549 W. Washington Blvd.
Chicago 6, Ill.
CEntral 6-1626

• *Entered as second-class matter at the Post Office at Manchester, New Hampshire. Accepted at special postal rate provided in paragraph (d-2), Sec. 34.40, P.L. and R., of 1918.*

• *Copyright by the Society of Plastics Engineers, Inc., 1961. Reproduction in whole or part without written permission is strictly prohibited.*

Member of the Audit Bureau of Circulations

AUDITED PAID CIRCULATION ABC

Standards, Codes, and Plastics

Having lunch with a friend recently (an old timer in the plastics industry), we mentioned that we thought there was a considerable market potential for plastic pipe. Further, we thought that the potential moved closer to reality with the acceptance by The Society of the Plastics Industry (SPI) of a tentative method for estimating long-term strength and working stress. This reasoning followed the rationalization that architects, builders, code officials, and others concerned with specifying pipe would accept plastic pipe more readily if they know performance data were determined by realistic and standard test methods. Friend's answer: Not so.

For one thing, our friend says, a large part of the potential lies in application to municipal distribution systems. When you enter this field, or for that matter the buildings and construction industry, you immediately get involved in politics, unions and insurance companies. And issues are not always resolved on the merits of materials alone. Finally, there is the ultimate consumer to contend with. Where his judgment is involved, resistance to innovation and change is often a problem. Upshot of the conversation with our friend was that he thought that realization of the full potential for plastic pipe and plastics in buildings was 15 years in coming.

Is this gloomy view correct? There are activities and developments in companies and organizations which *can* result in proving that our friend is unduly pessimistic. For example:

MONSANTO Chemical Company, has for some years now, exhibited an all-plastic house at Disneyland. This is a good way to lift technical and psychological barriers to plastics as materials of construction.

SPE now has a traveling exhibit entitled Plastics—A New Dimension in Buildings. The exhibit educates architects, engineers, builders, and students in the broadening applications of plastics as materials of construction.

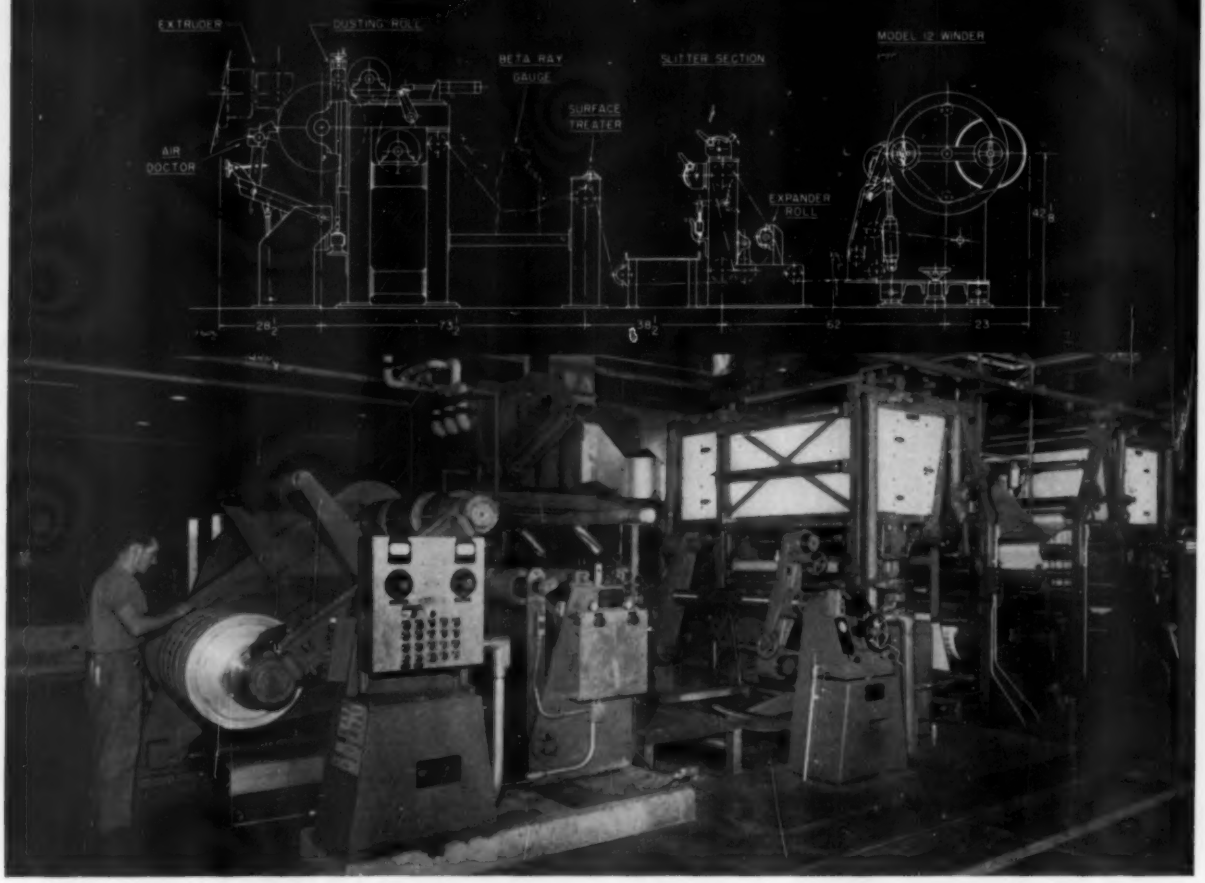
SPI and commercial standards are being developed at a quickened pace for new products to assure manufacturers that plastic products will meet (and surpass) established specifications and quality requirements.

NOTHING is so convincing as performance. If you're selling a product for a certain market, use it yourself. Allied Chemical Company, for instance, has used its own urethane insulating roof decking at two new plants and in its office building in New York.

People don't "buy" ideas. They buy what an idea will *do* for them. They buy solutions to problems. They buy benefits. That's why the benefits have to be spotlighted.

Complete "Package" Machine Lines

Extrusion Coating • Cast Film • Blown Tubing • Pelletizing



- Air Dryers, high or low velocity
- Drive and Control Equipment
- Extrusion Coaters and Laminators
- Laboratory & Pilot Plant Service
- Laminators, Polyethylene
- Slitter-Winders
- Take-Off and Cooling Drums
- Unwinds, continuous single, double or turret-type
- Winders, continuous surface and center type

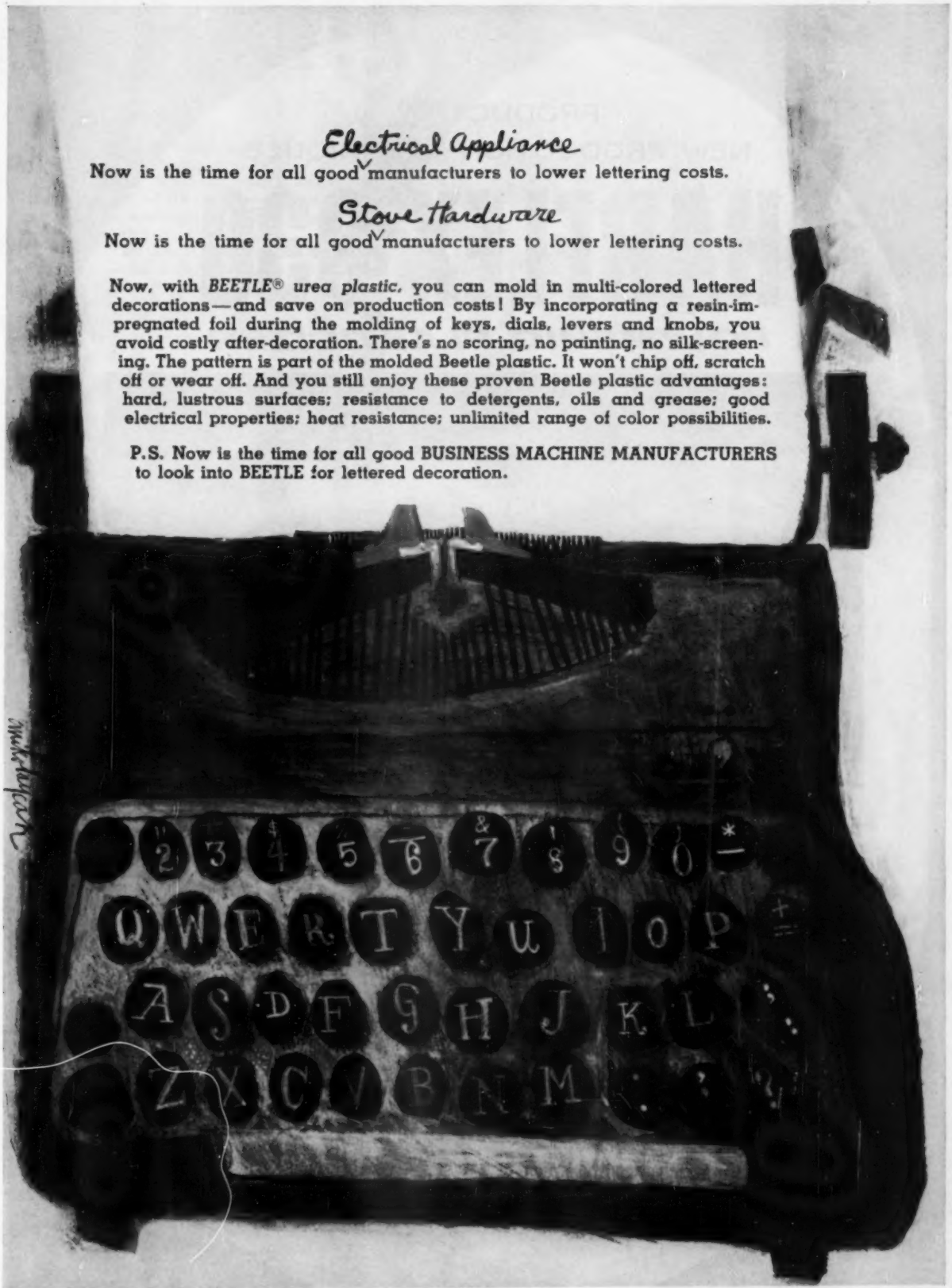
Direct inquiries to The Black-Clawson Company, Dilts Division, Fulton, New York

- Devolatilizing Systems
- Dies, Mark V flat film, coating, sheeting blown film
- Extruders, Aetna-Standard induction-heated, up to 10,000 psi, 1½" to 8" screw, 20:1 to 29:1 L/D Ratio
- Laboratory Extruders
- Plastics Pelletizing Systems
- Screen Pack Changers

Direct inquiries to The Black-Clawson Company, Hale and Kullgren Plastics Dept., 613 Tallmadge Ave., Akron, Ohio

DILTS DIVISION
Fulton, New York
CONVERT WITH CONFIDENCE

BLACK-CLAWSON


Electrical Appliance
Now is the time for all good manufacturers to lower lettering costs.
Stove Hardware
Now is the time for all good manufacturers to lower lettering costs.
Now, with BEETLE® urea plastic, you can mold in multi-colored lettered decorations—and save on production costs! By incorporating a resin-impregnated foil during the molding of keys, dials, levers and knobs, you avoid costly after-decoration. There's no scoring, no painting, no silk-screening. The pattern is part of the molded Beetle plastic. It won't chip off, scratch off or wear off. And you still enjoy these proven Beetle plastic advantages: hard, lustrous surfaces; resistance to detergents, oils and grease; good electrical properties; heat resistance; unlimited range of color possibilities.
P.S. Now is the time for all good BUSINESS MACHINE MANUFACTURERS to look into BEETLE for lettered decoration.

AMERICAN CYANAMID COMPANY CYANAMID PLASTICS AND RESINS DIVISION

Wallingford, Connecticut. Offices in: Boston • Charlotte • Chicago • Cincinnati • Cleveland • Dallas • Detroit • Los Angeles • Minneapolis • New York • Oakland • Philadelphia • St. Louis • Seattle • In Canada: CYANAMID OF CANADA LIMITED, Montreal • Toronto

PRODUCT OF
NEW PRODUCTION TECHNIQUES

HARFLEX® 330

POLYMERIC PLASTICIZER

NEW FREEDOM FROM VINYL UPHOLSTERY PROBLEMS

Newly improved Harflex 330 imparts durability and permanent flexibility to vinyls despite their subjection to perspiration, oil, soil, frequent washing with soapy water, chlorinated solvents, humidity, heat and sunlight. Eliminates windshield fogging from crash pad film.

Harflex 330 also assures freedom from taste and odor transfer to food from refrigerator gaskets. Its electrical properties include high dielectric strength, both dry and after water immersion.

Users find it offers unheard of uniformity and extreme efficiency with many other qualities of much costlier polymeric plasticizers.

Send for Sample, or Consult CHEMICAL MATERIALS CATALOG, Pages 159-161

WALLACE & TIERNAN INC.

HARCHEM
THE KEY TO BETTER PLASTICS

HARCHEM DIVISION | **25 Main Street**
Belleville 9, New Jersey

IN CANADA: HARCHEM LIMITED, TORONTO

Letters

Model Making

Dear Sir:

I am interested in securing a book on the processing of plastics to be used in model making. We make various kinds of models, as the U.S. Air Force requires these in the teaching of flight and maintenance of aircraft.

We are at present using wood and metal to make training aids, but feel that in a great many instances we could do a better job with plastics. Any information that you can furnish as to the proper book and source will be greatly appreciated.

Hardy Nolen
Enterprise, Alabama

Editor's Note

Mr. Nolen's request was referred to Mr. Edward Ferrari of the General Electric Co. in Bridgeport, Conn., Chairman of the Society's Casting & Plastics Tooling PAG. Mr. Ferrari's reply appears below.

The following references may provide assistance in building plastic models. These references are taken from the Casting Bibliography and some recent publications:

"How to Make Professional Molds and Castings", 1951 Boston Plastic Service Guild.

"Silicone Rubber Molds for Lower Mold Costs", Modern Plastics, Vol. 37, Sept., page 94.

"Silicone Products Data", General Electric Co.

"Technical Data" (Silicones), Dow Corning Corp.

"Technical Bulletin #12" (Polysulphide), Smooth-On Manufacturing Co.

"Technical Bulletins" (Polysulphide), Perma-Flex Mold Co.

"Economic Sampling and Prototypes With Flexible Molds", Industrial Models & Patterns, Nov.-Dec. 1960, page 14, Jan.-Feb. 1961, page 8, March-April 1961, page 8.

"How to Make Flexible Model Molds", Edward Ferrari, Modern Plastics, Vol. 31, July, page 93.

"Plastics Steal the Picture", Dr. H. Meyer, Modern Plastics, Vol. 35, March, page 141.

"Durez Casting Manual" (Phenolics), Durez Plastics Division, Hooker Electrochemical Co.

"From Appearance Design to Prototype Model", Edward Ferrari, S.P.E. Technical Papers, Vol. 3, 1957, page 62.

"Cast Epoxy Models", A. W. Wakeman —Product Engineering, Dec. 1959, page 58.

In addition to the above references the one independent model shop engaged in this work is Atkins & Merrill, Marlboro, Mass.

Edward Ferrari, *Chairman*
Casting & Plastic Tooling PAG

EXPERIENCE

that should carry a lot of weight with you

Lucidol has accumulated 35 years of experience in the development of organic peroxides and their compounds. Our products are distinguished by their quality and uniformity. Our fund of technical knowledge is at your disposal. Remember these facts when you seek a solution to processing problems involving the following peroxide groups:

Diacyl Peroxides • Dibasic Acid Peroxides • Ketone Peroxides • Aldehyde Peroxides • Alkyl Peroxyesters Alkyl Peroxides and Hydroperoxides Diperoxide Derivatives

Write for Data Sheets or See
CHEMICAL MATERIALS CATALOG, Page 179

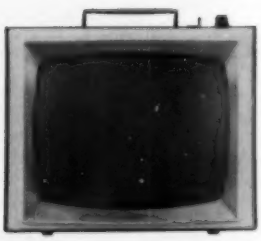
LUCIDOL DIVISION

WALLACE & TIERNAN INC.
1740 MILITARY ROAD
BUFFALO 5, NEW YORK

BAKELITE® High-impact, Heat-resistant

PERFORMANCE-PROVED BY

ADMIRAL parts molded of TMD 5161 by Superior Plastics, Inc.; J. P. Gits Molding Corp.



GENERAL ELECTRIC parts molded of TMD 5161 by Buffalo Molded Plastics, Inc.; Plastic Inlays, Inc.

PHILCO parts molded of TMD 5161 by Champion Molded Plastics, Inc.; Buffalo Molded Plastics, Inc.; St. Regis Paper Company.

SYLVANIA parts molded of TMD 5161 by Buffalo Molded Plastics, Inc.; Presque Isle Plastics Inc.; Plastic Inlays, Inc.; St. Regis Paper Co.

WESTINGHOUSE parts molded of TMD 5161 by Plastic-Ware, Inc.; St. Regis Paper Co.

WARWICK (Sears-Roebuck) parts molded of TMD 5161 by Sinko Mfg. Co.; General American Transportation Corp.; Amos Molded Plastics; Plastic-Ware, Inc.

Styrene TMD-5161

THESE TV LEADERS!

It could be the answer to your parts problems!

If you require heat resistance in a high-impact styrene . . . good retention of impact strength . . . high gloss . . . useable toughness at low temperatures, BAKELITE TMD 5161 has them all! It possesses the good molding latitude and flow properties of lower impact, less heat-resistant styrene grades.

General acceptance by leading TV manufacturers for assembly-line production of portable cabinets and large intricate parts is proof of its outstanding performance characteristics.

Versatile BAKELITE TMD 5161 is also used for housewares, automotive, and industrial applications where a combination of heat resistance and high-impact strength is desired.

Want more information? Write Dept. IS-132G, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Ave., New York 17, N. Y. *In Canada:* Union Carbide Canada Limited, Toronto 12.

UNION CARBIDE

BAKELITE and UNION CARBIDE are registered trademarks of Union Carbide Corporation.

Pressure-temperature operation is here!

Research by Barber-Colman and cooperating members of the Plastics Industry has proved the practicality of pressure-temperature operation. Pressure indication speeds return to best mixing conditions and gives faster read-out of screw or screen troubles. Savings up to 1/3 have been reported by users. The new instruments below are specifically designed to aid plastics production. Ask your Barber-Colman Sales and Service Engineer today.

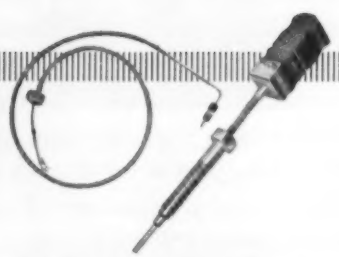
Record any combination of pressure and temperature up to 24 points

The new Series 8000 Multipoint Recorders are electronic potentiometer instruments with zero and span adjustment for the pressure range. Dual 11″ scales indicate temperature and pressure. Accuracy is ±¼ of 1% in typical ranges between 0-800°F and 0-10,000 psig. Zener diode constant voltage source. Up to six high or low limit switches. Swing-away chassis. Series 2000 Round Chart Recorders are available for r.p.m. or foot-per-minute control of plastic sheet roll units.

Now you can indicate temperature or pressure on only one instrument while controlling temperature. Simply flip the selector switch. The new Series 400 Capacitrol Indicators offer 6″ direct reading scale, and high or low limits.

Series 400 Capacitrols indicate and control temperatures. Available with Truline "anticipatory" time proportioning. Accurate 6″ scale . . . famed no-contact "Electronic Link"...plug-in chassis. Sensitive, accurate and reliable.

Specially designed for the plastics industry, Model 297 Capacitrols offer accurate "Electronic Link" and built-in anticipating control. Easy-to-read 5″ scale, plug-in components, compact size. Sensitive, dependable and economical.



Barber-Colman offers a complete line of sensing devices and control accessories . . . thermocouples, pressure transducers, radiation detectors, resistance bulbs and pyrometers. Make Barber-Colman your control headquarters today.

BARBER COLMAN

BARBER-COLMAN COMPANY

Wheelco Industrial Instruments Division

Dept. S, 1575 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. S, Toronto & Montreal • Export Agent: Ad Auriema, Inc. N.Y.

SPE JOURNAL NEWSLETTER

reading time
1 minute

More Polyethers on Stream

The first plastics company to supply all major components of urethane foam—diisocyanates, blowing agents, and polyethers—will be Allied Chemical Corp. Most of the 70 to 80 million pounds of polyethers to be made in the U.S. in 1961 will go into flexible urethane foam for furniture, bedding, and automotive seating. Other polyether markets are in rigid urethane foam for thermal insulating and marine flotation applications.

Soviet Plastics

As more and more Americans visit Russia, our general impressions of their work in plastics become clearer. For instance: Liaison between their scientific work and their engineering is much better than in the U.S.; they are particularly interested in moving forward in the field of reinforced plastics. Of interest is the fact that the Soviets have set up 23 guidelines for basic research. Number 7 on the list: Polymers.

Piping to Make Gains

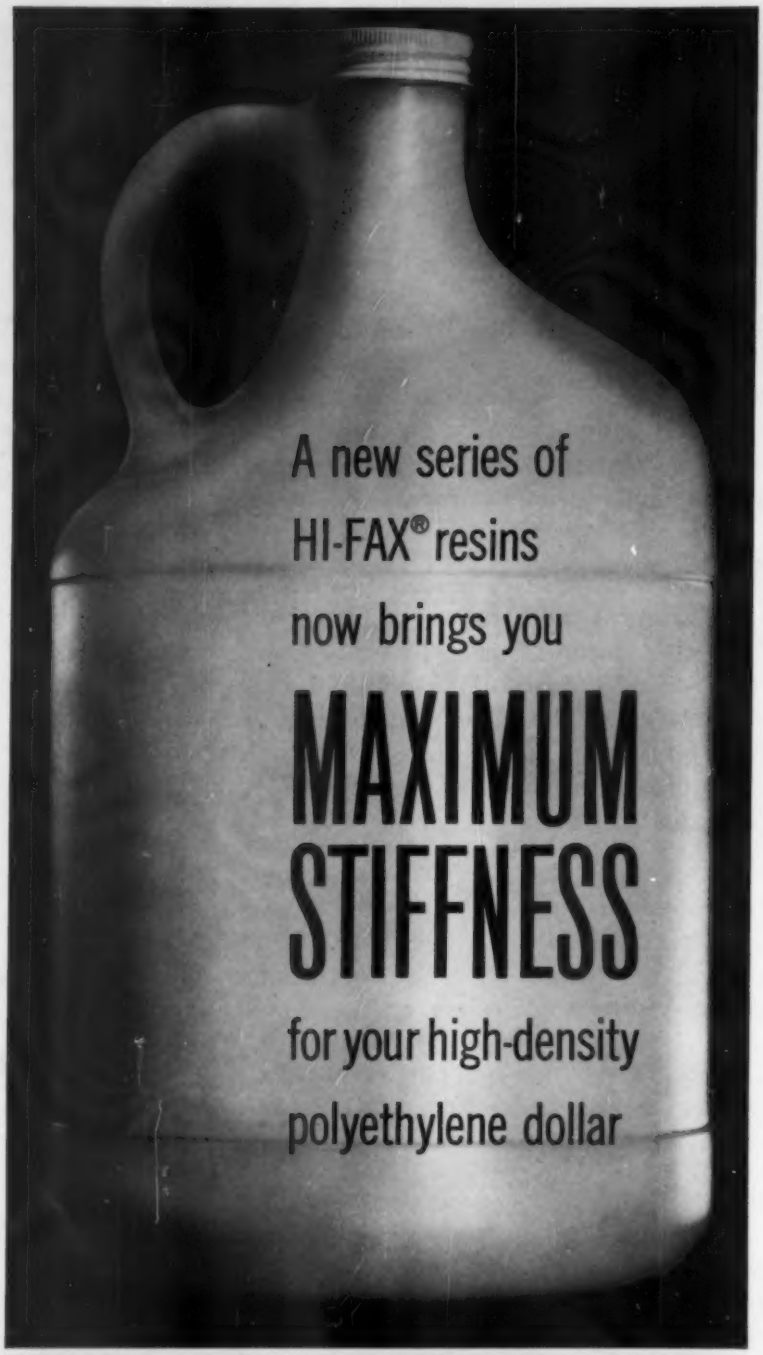
The potential growth of thermoplastic pipe may be sharply increased with the adoption by SPI of a tentative method for estimating long-term strength and working stress. Architects, builders, and code officials will probably first turn their attention to water and gas distribution systems, both inside and outside of buildings. Add to this the recent announcement by the Federal Housing Authority that it has approved polyethylene pipe and fittings for use in carrying potable water.

More Plastics in Autos

Most 1962 automobiles will be carrying poly(vinyl chloride) floor mats, for the first time. The new mats are reportedly priced to be competitive with rubber mats, and have resistance to oil, grease, abrasion, and puncturing.

Plastics Exposition A Success

More than 35,000 persons attended the recent National Plastics Exposition held in New York. The Society of the Plastics Industry (SPI), sponsors of the event, reported that the attendance amounted to an increase of about 30% over the last Exposition held in Chicago in 1958.



NEW 0.962 HI-FAX RESINS

Series	Melt Index
Hi-fax 2600 E	0.2
Hi-fax 2400 E	0.9
Hi-fax 2300 E	1.5

Hi-fax® is the Hercules Powder Company registered trade mark for high-density polyethylene.

Another first for Hi-fax: 0.962-density resins in three different melt indexes. Produced by the exclusive Hercules process with Ziegler catalysts, this new economy form of Hi-fax is the first material of its type commercially available in America. Check these outstanding features of this important addition to the Hi-fax family:

Maximum stiffness
Superior surface gloss
Sharper light transmission
Increased resistance to permeation
Low cost

Add to all this the established processing advantages exclusive with Hi-fax, and the door is opened to a whole new vista of profitable markets.

Liquid bleach packaging appears to be one of the largest potential markets for these new Hi-fax resins. With its high degree of stiffness and excellent resistance to permeation, 0.962-density Hi-fax is one of the few materials capable of handling this hard-to-package product. In toys, sporting goods, durable housewares, and containers for motor oil, waxes, and a variety of household and industrial chemicals, blow molders are already making use of its improved surface finish, translucency, and merchandising appeal.

The scope of this versatile new resin reaches beyond blow-molding markets to such fields as extruded monofilaments, rigid sheets for vacuum-forming, and injection molding . . . wherever its outstanding stiffness, impermeability, and attractive surface finish provide the product advantages you require.

Extensively tested both in the laboratory and the market place prior to its introduction, 0.962-density Hi-fax is available now in whatever quantities you require . . . from a single bag to a 100,000 lb. Dry-Flo car. Attractively priced, it brings you that extra plus in properties and processability that made Hi-fax the pioneer . . . and still the leader of high-density polyethylenes.

Get thoroughly acquainted with 0.962-density Hi-fax resins. Write for all the facts.

HERCULES POWDER COMPANY
INCORPORATED
Hercules Tower, 910 Market Street, Wilmington 99, Delaware

CP61-9

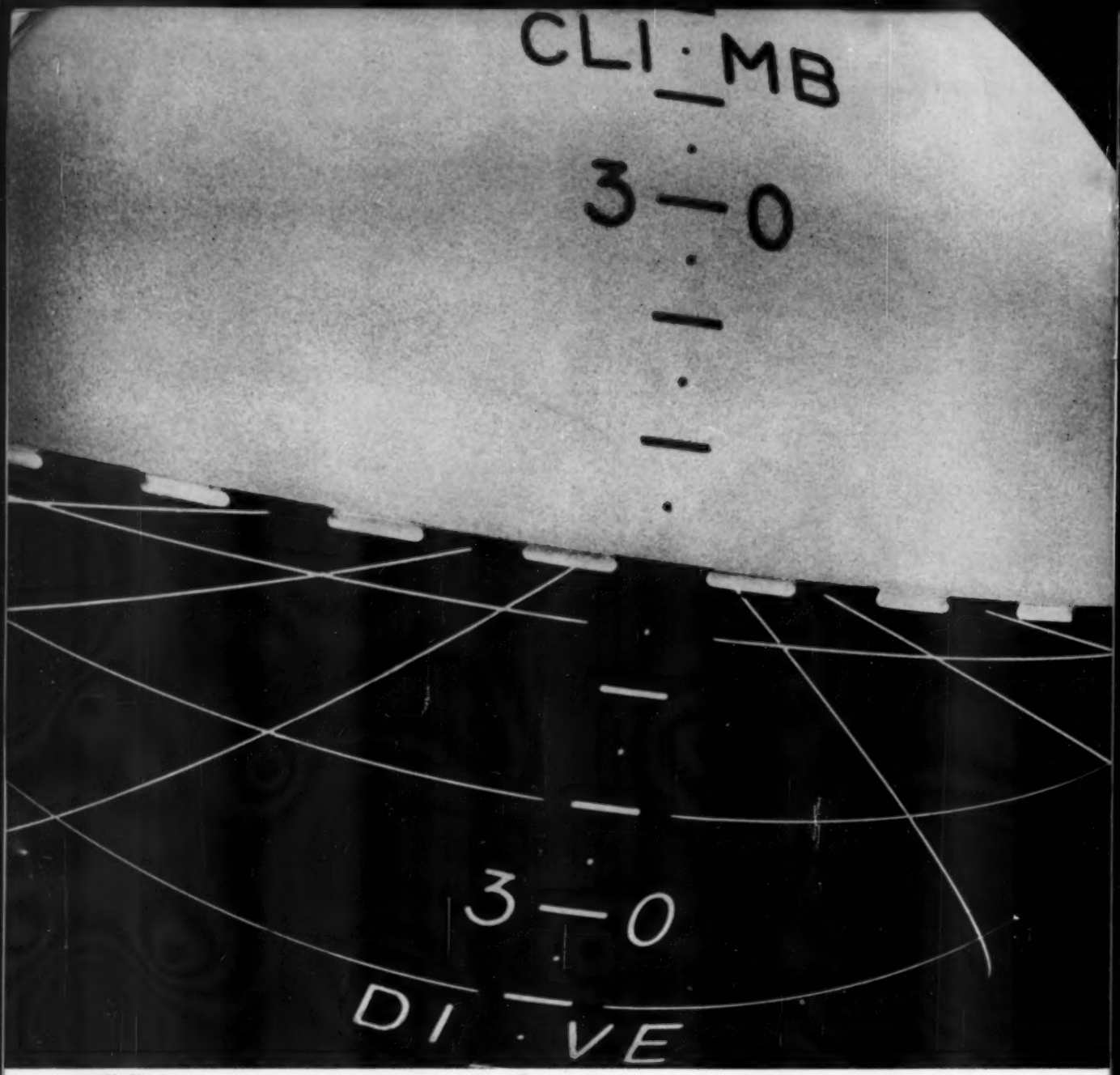
GEM-LIKE QUALITY IN CADMIUM TONERS & LITHOPONES

Brilliant color • Unusually permanent • Excellent heat and light resistance • Exceptionally stable to alkali • Non-bleeding

Write today for latest information on cadmium sulfides, selenides and mercury sulfides. Consult our special shade-matching service.

GENERAL COLOR COMPANY

24 Avenue B, Newark 5, New Jersey/Division of H. Kohnstamm & Co., Inc.



Lexan resin provides dimensional stability in close-tolerance parts

Maximum change allowable in the overall dimensions of this five-inch attitude indicator component is only 5 mils over a temperature range of –65° to 300°F! Moreover, the aircraft instrument part must maintain these tolerances under conditions of high humidity. To meet these severe requirements for dimensional stability, Lear, Inc. selected LEXAN polycarbonate resin.

In addition to high performance, LEXAN offers easy and versatile fabrication. Thermoplastic, it is injection molded in half spheres which are joined by solvent cementing. After lathe turning to insure complete accuracy, the spheres are painted three different colors. Maximum visibility is obtained by lighting from the inside. With their high temperature resistance and high impact strength, these polycarbonate spheres are both rugged and precise design elements. They are fabricated for the Instrument Division of Lear, Inc. by Monroe Industries — both of Grand Rapids, Mich.

This component is an example of what high-performance LEXAN polycarbonate resin can do for your designs. The price of the resin has gone down, too, as production has gone up. Can *you* afford to overlook the major advantages of this new, major design material? Send for design literature.

LEXAN®
Polycarbonate Resin
GENERAL ELECTRIC

Chemical Materials Dept., Section SPE-41, Pittsfield, Mass.

Please don't thank us. At Spencer, we consider it our privilege to tackle your problems as though they were our own. It may mean formulating a custom resin. Pioneering a new application. Making a study of market potential. Spencer welcomes the opportunity to assist you in any phase, from product development to final sale. Working closely with you is all in the Spencer way of doing things. Spencer CARES. If you use polyethylene, polypropylene or nylon in any way, your nearest Spencer representative is eager to be of service. Just write us at the address below. He will contact you promptly.

The Company Known For Its Know-How

SPENCER

"Poly-Eth"® Polyethylene · "Poly-Pro"® Polypropylene · Spencer Nylon

Spencer Chemical Company
Dwight Building, Kansas City, Mo.

SPE Meeting to Feature New Tooling Developments

Recent rapid progress in the application of plastics for tools will be highlighted at an SPE Regional Technical Conference sponsored by the Central Indiana Section in Indianapolis, Indiana, on September 12, 1961. The technical program of this "Plastics for Tools" Conference, to be held at the Severin Hotel in Indianapolis, has been specially developed to be of interest to both plastics and tool engineers alike.

Emphasizing new developments in plastics tooling, the program will be broad in scope covering materials, methods, equipment, applications, design and safety, according to RETEC Chairman Eugene C. Quear of the Delco Remy Div. of General Motors. A concluding panel discussion will provide an opportunity for an interchange of technical information and questions on topics of specific interest.

Members of Muncie Chapter of ASTME have cooperated in planning and organizing the meeting and all ASTME members are offered the same registration privileges as SPE members. The complete technical program, featuring nationally recognized speakers in the plastics tooling field, as announced by Program Chairman John A. Shelton of duPont, is as follows:

PLASTICS FOR TOOLING

September 12, 1961
Hotel Severin, Indianapolis, Indiana

8:30 a.m. —Registration

MORNING SESSION

Moderator: **John A. Shelton**
E. I. du Pont de Nemours & Co.

9:30 a.m. **—Materials for Plastics Tooling**
Joseph W. Tierney—Hysol Corp.

10:00 a.m. **—Design and Construction of Plastics Tools**
Wayne Camp—Ren Plastics, Inc.

10:30 a.m. **—Extrusion Molding Large Prototype Parts**
John Houston—E. I. du Pont de Nemours & Co.

11:00 a.m. **—Compression and Laminating Molds**
W. Leeds Frye—Tooling Aids, Inc.

12:00 noon Luncheon
SPE—Present and Future
John Delmonte
SPE Vice President, Administration
and
industry speaker to be announced

AFTERNOON SESSION

Moderator: **Carl A. Darger, ASTME**
Carl A. Darger and Associates

2:00 p.m. **—Equipment and Safety**
A. Helle & John Delmonte—Furane Plastics, Inc.

2:30 p.m. **—Jigs, Fixtures and Gages**
C. S. Cerquettini—North American Aviation

3:00 p.m. **—High Temperature Epoxy Resins for Injection Molds**
Irving E. Poston—General Motors Manufacturing Development

3:30 p.m. —Panel Discussion

Major RETEC Committee Chairmen, all members of SPE's Central Indiana Section, are: House—William K. Millholland, Millholland & Conrad; Printing—P. J. Eflin, Delco Remy Div. of General Motors Corp.; Publicity—Stephen D. Ransburg, Radio Corp. of America and Keith A. Weston, Western Electric Co.; Treasurer—Leon L. Davis, Hydraulic Press Manufacturing Co.; and ASTME Representative—Jess Lollar of the Muncie Chapter.

Registration fees, which include luncheon and a complete set of technical papers, for this Conference are as follows:

	SPE and ASTME Members	Non-Members
Advance Registration	$10.00	$12.00
Conference Registration	$11.00	$13.00

Requests for further information and advance registrations should be directed to:

W. G. McMahan
RETEC Registration Chairman
c/o Guide Lamp Div.
General Motors Corp.
Anderson, Ind.

U.S.I. POLYETHYLENE NEWS

A series of advertisements for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

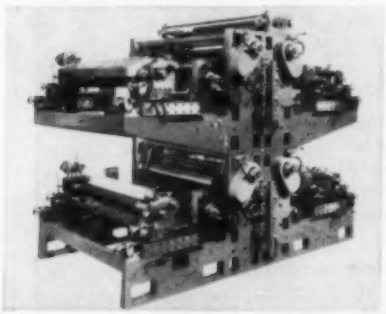
Packaging Notes

Paste spackling for patching cracks and nicks in plaster, wood and wallboard is now convenience-packaged in a ½-pint polyethylene tube. The manufacturer points out that easy, one-hand operation of the tube allows the user to keep the other hand free for spatula or putty knife.

Versatile hand-welder for polyethylene can be used for tacking or high-speed

welding at a production rate of 60 in. per min. Patented design maintains constant flow of high-temperature air through specially designed tips. Unit has a 3-heat metal element with an output of up to 800 watts and a 16-foot air-hose (with electric cable inside). Can be plugged into any 115 volt a-c outlet.

Expandable flexographic press permits the converter to add color units on a "building block" principle—lowering ini-



tial investment, yet allowing for future expansion. Side frames of additional units are merely bolted onto special prebored fittings within the existing frame.

This press is designed for use in in-line extruding and bag making, as well as roll-to-roll printing. It can print up to six colors, comes in sizes to accommodate web widths of 24 to 42 inches.

Polyethylene-coated cartons are now being used for chilled orange juice as well as milk. Leaking and flaking—shortcomings of wax-coated containers—have reportedly been virtually eliminated.

Polyethylene Film Extrusion Operators' Guide Issued By U.S.I.

New 56-Page Manual First of Kind to Be Offered by a Raw Materials Producer

"Polyethylene Film Extrusion . . . An Operating Manual" has just been published by U.S.I. The new 56-page booklet is the most complete and useful guide to efficient polyethylene film extrusion ever published. The first comprehensive manual prepared by a resin producer expressly for film extruder operators, it represents a major effort by U.S.I. to improve and standardize polyethylene film.

The booklet provides the extruder operator with everything he needs to know to make the best possible polyethylene film at the most efficient production rates. It distills the experience not only of U.S.I. sales and technical service departments, but also of many extruders themselves. It presents this information in easy-to-understand terms familiar to everyone — those who operate and maintain extrusion equipment, as well as their supervisors.

Pages 14 & 15 of U.S.I.'s new information-packed 56-page booklet which is available through U.S.I. salesmen.

First the Basics...

For workers new in the field, this manual provides such fundamental information as what polyethylene is, how it's made and how modifications of its basic molecular characteristics affect resin and end product properties.

A section on what happens to the polyethylene resin on its way through the film extruder follows. Included are simple diagrams of the extrusion machine and explanations of the functions each part performs.

Next come tips on how to open a polyethylene resin bag properly to save time and minimize contamination problems.

Then the Particulars

The core of U.S.I.'s new manual helps define the problems operators and maintenance men have to cope with and offers some practical solutions. Specifically there are chapters on: melting the resin; film cooling and frost line; the blown film bubble; take-off and windup equipment; checking and keeping a record of extruder controls; cleaning the extruder; means of increasing output and improving quality. The last contains a full-page table listing the most common defects in extruded film and their possible causes.

50 Do's and Don'ts

The booklet winds up with some basic safety rules and a checklist of some 50 Do's and Don'ts, which is also available as an 11" x 15" wall chart for posting near the extruder.

Copies of the operating manual and poster can be obtained through your U.S.I. salesman. Sales office branches are found in most large cities. Ask your U.S.I. salesman for your copy and extra copies for your plant operators.

Best in Show

This toy dog wins a blue ribbon for demonstrating a new and unique use of polyethylene film. It's cleverly fashioned by a Texas woman whose deft hands also transform polyethylene film into toy rabbits, Christmas wreaths.

The poodle comes in black, white or pastel colors. Model shown sells for approximately seven dollars.

New Blending Resin Introduced by U.S.I.

Development of a new injection molding blending resin, PETROTHENE 250 Polyethylene (density 0.926, melt index 250), has just been announced by U.S.I. Very high flow and ease of blending are its key properties.

It can be blended with lower melt index resins to improve their flow for injection molding or used alone for non-critical injection molding applications.

In trial runs at U.S.I.'s Polymer Service laboratories, items molded from blends of PETROTHENE 250 and lower melt index resins had physical properties superior to those molded from blends utilizing polyethylene waxes. Also, items molded from the straight resin exhibited very high gloss and good surface smoothness, as well as good stiffness and high impact resistance at room temperature.

U.S.I.

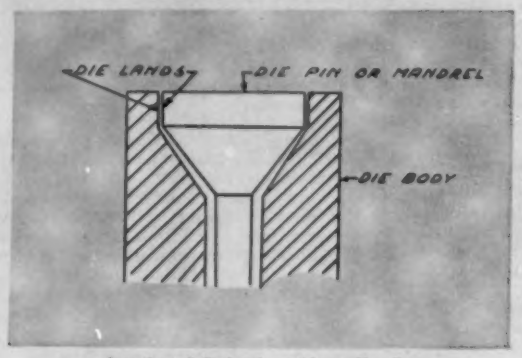
Series VI, No. 4

POLYETHYLENE PROCESSING TIPS

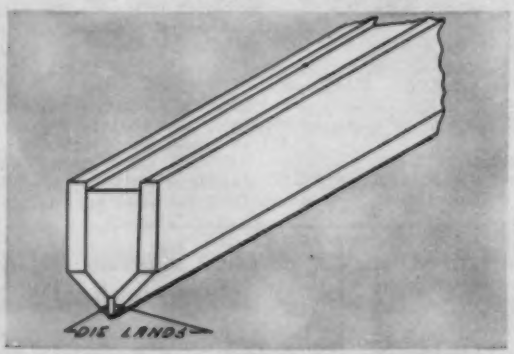
CARE AND CLEANING OF EXTRUDER DIE LANDS

In polyethylene film extrusion and extrusion coating, the die lands (see diagrams) must be kept clean and free from nicks and scratches. These are the final surfaces over which the hot melt passes before leaving the die, and which shape the hot plastic and help to produce smooth surfaces. Any surface irregularities in the lands show up as lines or streaks in the plastic. If severe, they weaken the film, but in any case, they are undesirable since they spoil film appearance.

Oxidized particles are a major cause of rough die lands. If proper care is not taken, small raised areas of oxidized plastic can form on the lands, marking the film as it passes by in the hot melt stage.



Location of die lands on blown film die.



Location of die lands on flat film and extrusion coating die.

Preventing Oxidized Polymer Build-Up

Oxidation is more of a problem in flat film extrusion (chill roll or water quenched) and extrusion coating than in blown film extrusion. That's because these require much higher temperatures, which promote oxidation. Care in shutting down the flat film extruder or extrusion coater will reduce the problem of oxidized polymer on the die lands. Simply shut off the temperature controls and let the hot melt temperature fall below 400°F before shutting off the screw.

Several other precautions will cut polymer build-up on the lands in all types of equipment. A simple method is to remove oxidized polymer daily, or more often, use a brass blade which is thinner than the die opening. The blade should be dull and have a rounded tip so it won't mark the hot lands. Insert it between the lands and push it along their length (or around their circumference, in the case of blown film). The blade should always be pushed around or across the entire surface of the lands—never in and out at one spot.

A second step in keeping die lands clean and smooth is to schedule a complete cleaning on a regular basis. How often is best determined through experience. In most cases, cleaning at least once a week is necessary.

Cleaning Procedures

In blown film extrusion, the die lands are a part of the die body and mandrel. Hence, in cleaning the lands, the entire internal die surface is cleaned as well. Following is the recommended procedure:

1. Remove die from extruder while it is hot.
2. Pull mandrel or die pin from die body.
3. Scrape excess polymer from die pin and die body with a soft metal (brass or copper) or wood instrument.
4. Remove the last bits of polymer with brass or copper wool.
5. Polish mandrel and internal surface of die body, using a very fine grit cleaner (2400 grit lapping compound is used at U.S.I.'s Polymer Service Laboratories) on a soft, damp cloth or tissue.
6. Give lands a light coat of silicone grease.

A similar procedure is followed for the lands of flat film and extrusion dies. First remove the die jaw while hot—but below 400°F. Next remove the die lands from the jaws if they are separate. Then clean the jaws and lands as in steps 3 and 4 above, and polish and coat the lands as in steps 5 and 6.

A Word of Caution

In cleaning and polishing die lands, *never* let a screw driver or other hard metal tools touch the lands; they cause nicks and scratches. *Always* clean and polish with smooth, even strokes in a direction perpendicular to resin flow; this eliminates the danger of rounding the die lips.

Cleaning procedures outlined above will substantially reduce the amount of off-quality film resulting from contaminated die lands. However, from time to time, the lands will have to be refinished either by honing or, if they are chrome plated, by replating. U.S.I. Technical Service Engineers can give you advice on these procedures.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
Branches in principal cities

Special Feature

Plastics for the Automotive Industry

On May 9, the Detroit Section held a successful Regional Technical Conference (RETEC) in which close to 400 people participated. The six papers presented at the Conference appear on the following pages in condensed form. Mr. Robert McLean of General Motors Corporation spoke on, The Autoline—and Plastics, at luncheon. He described automated super-highways capable of handling large numbers of automobiles at speeds of 150 miles per hour and of the place that plastics would have in this field. A display on plastic parts used in the automotive industry was exhibited in the lobby of the hall where Mr. Sturzl started the day's discussions with his talk, Instrument Cluster Plastics—Past, Present and Future. The morning and afternoon moderators respectively were Mr. W. P. Gobeille of American Motors Corporation and Dr. E. J. Storfer of Chrysler Corporation

Instrument Cluster Plastics Past, Present, Future

Henry C. Sturzl

AC Spark Plug Division
General Motors Corporation

An instrument cluster can be considered as a functional grouping of the various gauges and controls necessary to operate a vehicle. Since 1930 however the importance of the aesthetic function grew so that today an instrument cluster has become an important element in the decor of a car's interior.

Without question, the conventional materials that have been used, such as, die castings, sheet metal stampings, rubber gaskets, glass and plastic lenses, have been very satisfactory. These conventional materials have some shortcomings and disadvantages however. Die castings usually require a considerable burring and trimming. Unless this can be done in areas not visible to the driver, this operation can spoil the appearance of the part. It is also time consuming and costly. Sheet metal stampings are limited as to contours and the depth of draw. Weight has also become a major concern in recent years whenever zinc die castings are used. This item alone affects every person that must handle the part from raw material to final assembly. However, thru the use of plastics materials available today, many of these disadvantages can be overcome.

A typical example is a General Motors Truck cluster. There are just two basic moldings; namely, the face which is made of acrylic plastics and painted except for the window areas, and the case which is made of an ABS plastics. The case includes integral printed circuit wiring which supplies current to the instruments, telltale indicators and lighting lamps. Through this type of wiring, car assembly is simplified and improper connections are eliminated.

Buick Cluster

The remainder of this paper will be a case history of the design and development of the Buick Special cluster shown in *Figure 1*.

This design as it came from the General Motors Styling Section, seemed to be a natural for plastics. Here are six of the factors that were instrumental in arriving at this conclusion:

1. It was large enough to be challenging, but yet not too large.
2. Its contours were such as to require extensive trimming, burring and fitting if it were made of die cast metal.
3. Some parts were practically impossible to make of stampings.
4. The way it mated with the dashboard and the way the mounting lugs were arranged indicated this cluster would lend itself to a very practical support system.
5. Because of its designed shape, which is somewhat overhanging, the reduction in weight of a plastics unit would be very beneficial.
6. Plastics answered two problems relative to the case, which is

Figure 1. 1961 Buick Special Cluster

a functional part. The complex configuration could easily be obtained and a customer requested printed circuit could be applied directly to the material.

In *Figure 2* is shown the comparison between the single unit Buick printed circuit case and the conventional type printed circuit assembly and detail parts. The decision to use one or the other is usually based on many factors such as design, structural and space requirements, customer acceptance, anticipated volume and, as always, cost which could favor either design.

Selecting the Material

A review of some typical materials showed;

1. acetal resins seemed too costly
2. polypropylene is not readily paintable
3. modified acrylics have low heat resistance and low impact at colder temperatures
4. polyester fiberglass premix has a rather poor surface finish and may be more costly due to long cure time in the die
5. polycarbonates have high material cost and painting problems.

On the other hand, investigation of the ABS family showed that there was one grade of this family that came fairly close to meeting all the requirements. Nine significant advantages of this material are;

1. its cost is not excessive
2. its impact strength is fairly good
3. it will accept the acrylic lacquers that are commonly used in car interiors
4. its toughness over a wide temperature range is favorable
5. it can be made opaque without seriously affecting any of its properties
6. its temperature resistance, even though borderline, is in the "safe" range
7. it is fairly rigid throughout the useable temperature range and it does not become brittle in the low ranges
8. there were several years of experience and background information available since 1954 on its use in similar applications on European cars.
9. a background of two years of successful experience using this material on the GM Truck cluster case was available.

Testing Program

A number of tests had been established that could be applied to production parts. These tests can be broken down into three groups;

1. heat and humidity
2. vibration
3. tests conducted by Buick at the Arizona Proving Grounds.

The results of the tests are summed up as follows:

1. All three clusters passed the test for paint adhesion, fogging shrinkage and warpage, done for eight hours at 170°F and 95% relative humidity. ABS could reach a temperature of 225°F before deformation became apparent.
2. Damaging resonance at room temperature developed at about 39 CPS (57 CPS at −20°F). No significant damage resulted from testing in three planes with frequencies ranging from 10 to 100 CPS
3. On June 17, 1960 Buick engineers placed one of these clusters into a car for exposure to a high sun load. The car was a regular test car, painted dark blue, having clear glass, and set so as to receive the maximum radiation from the sun.

These facts may be readily visualized by referring to the graph as shown in *Figure 3*.

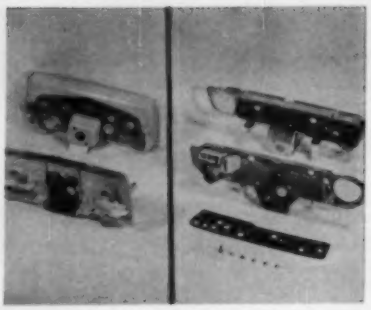


Figure 2. Comparison of two types of printed circuit design. Left hand picture is the single unit Buick circuit base

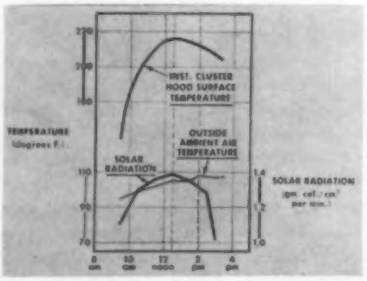


Figure 3. Solar exposure tests of June 17, 1960

No sign of deformation was observed at 216°F under direct exposure to the sun's rays, even after soaking for four weeks. A black cluster was then deemed perfectly acceptable.

Ideal Future Plastics

As a suggestion for an ideal plastics of the future, consideration should be given to the following properties;

1. sufficient rigidity so that it could be used as a supporting member
2. heat resistance of approximately 250°F with enough strength to hold its shape under a light load at this temperature
3. paintability with automotive lacquers
4. chemical resistance to ordinary cleaners
5. satisfactory surface finish so as to permit metallized surfaces
6. dimensional stability under normal operating temperatures
7. a minimum of highly volatile matter to eliminate fogging
8. opaqueness without losing desired properties
9. ability to be molded in a variety of colors.
10. high rate of thermal conductivity.

Development and Growth of Decorated Plastics in the Automotive Industry

Milton Thorson

Vice President
Red Spot Paint & Varnish
Evansville, Indiana

In the latter part of the 1930s, acetate, butyrate, crystal polystyrene and acrylic resins began to make themselves known in the industry, where it is believed that Nash was the first to use decorated plastics. The use of butyrate in the dash panel required that paint formulas be changed daily to keep up with the changing color of the molded plastics themselves.

In the appliance industry, Sears, Roebuck & Co. brought out a Coldspot refrigerator, utilizing for the first time completely painted interiors and second surface decorated polystyrene. It is believed that the first automotive emblem of plastics was a Ford emblem of methacrylate.

One influencing factor, outside of development of plastics, was the impetus and utilization of high vacuum metalizing (first used on polystyrene) for the creation of the then new dimensional color technique. In 1953 a serious attempt was made to utilize first surface metalizing in the automotive industry.

Breaking simultaneously with the decorated plastics industry was development of improved plastics and slow improvement in coating resins. The decorating industry is attempting to overcome the inherent weaknesses that are evident in any system based on organic compounds. Slowly emerging is improved quality, which will further broaden the utilization of plastics and possibly improve appearance of the finished product, enhance the safety factor, reduce weight and lower costs. Development of newer type thermoplastics of high impact and high heat characteristics has led to still further utilization of plastics for first surface painting and decorating. More heat applied during decorating can result in more desirable properties.

It is necessary to develop laboratory procedures for the improvement of quality. The basic elements of appraisal are heat, humidity sunlight, abrasion, adhesion, chemical resistance, lamination, color retention, mar resistance, appearance and general workmanship.

Specifications

Much work in the early days was done without specifications as to performance requirements. When these specifications were written, there were so many factors involved that it was difficult to determine suitable and adequate quality. Specifications in second surface decoration of plastics, although improved, are still one of the most difficult to appraise from a laboratory standpoint.

The most important long range appraisal comes from actual exterior exposure. This takes into account all of the factors involved—sunlight, humidity, galvanic corrosion, fastening and adhesive attachment. Considering the vast number of coatings involved in high vacuum metalizing and backcoating systems, testing and formulation of data becomes exceedingly complicated.

Additional specifications are necessary under certain conditions. If internal coloring is used to supplement decorating, some check must be made for lubricants, bleeding, light fastness and heat resistance. First surface metalizing becomes more complex with a variety of special color effects, sometimes in the form of overlays. Specifications covering these overlays are as important as specifications covering the metalizing itself.

In the second surface field, Florida field tests are used as the basic gauge for judging improvement. Revision upward of specifications initially brought out in the metalizing industry for determining quality are now in process. Abrasion resistance, one of the weakest phases of high vacuum metalizing on plastics, has shown a rapid improvement.

Some Future Developments

In the development of better products, a wider scope of examination of the factors that affect quality will result in studies of plant sanitation, air pollution and dirt control. Dirt control studies are being inaugurated and the effect of these upon quality will be one of the most important contributions toward advancement of the decorating industry. Approval of facilities for production of the components, will probably be a part of future purchasing procedures. Hand wearing areas on plastics will be a reality one day and exterior use is being examined and studied. New developments in first surface high vacuum metalizing indicate that this method should have a large impact on the industry.

Experienced Inexperience

J. W. Greig

Woodall Industries, Inc.
Detroit, Michigan

The rapid growth and development of so many new plastics materials is creating a problem for the plastics engineer. The problem is one of obtaining, organizing and simplifying information and acquiring experience with the vast number of plastics materials.

In order to obtain the maximum results from all of the factors involved when marketing and producing items fabricated from a new plastic material it is necessary to form a chain of action which is composed of all interested parties. The chemists who have developed the material, the applications engineers and the chemical company who supplies the risk capital, must all be interested in solving their common problem of applying the untried material correctly. Although each of these people may be inexperienced at the outset, they may benefit together from the experience of inexperience, while learning the properties of that plastic more fully.

Through a properly coordinated chain of action the plant engineer should obtain better material standards and at the same time inform the supplier more accurately of his needs so that they may be catered to; misapplication should be prevented. It is said that there is no such thing as a bad material—only its poor application.

Important Considerations of Molding Applications on the Automobile

R. S. Giles

Manager, Plastics Research and Development
American Motors Corporation
Detroit, Michigan

The key to proper application of plastics is to understand (1) their characteristic properties and the stress effect the specific physical, chemical and structural conditions of use will have on the fabricated part; (2) their methods of fabrication; the advantages and disadvantages in product design to be gained by various methods; and (3) the effect of the fabrication process upon properties, an element of fundamental importance.

Design Techniques

In the application of design techniques to thermoplastic structures, the designer should understand the basic elements of design for thermoplastic parts—draft angles and ample flow paths, for example. He must then turn to the physical properties necessary to perform the function set up for the part.

In sheet metal design, materials having a flexural modulus of 29,000,000 psi are considered. In thermoplastics materials having flexural moduli in the range of 200,000 to 500,000 psi are generally encountered. In a specific thermoplastic design, it might be necessary to require a certain wall thickness so that the stresses will never exceed a factor of ¼ or ½ the indicated modulus figure. In considering a similar design in sheet metal, it is rarely necessary to compute stress levels for metal thickness. A

stiffness value of 100,000 psi hardly merits consideration because the designer is dealing with a material having a tremendously high flex modulus. In other words, a factor of safety of 200 to 300 is obtained; the designer is accustomed to this extra margin. Not so with thermoplastic materials for here design stresses are appreciable percentages of the available total strength.

In injection molding, viscous flow into or through narrow passages directly effects the induced stresses of the finished part. Thus for various of these thermoplastic materials, the width of a passage has a definite minimum value. This affects the designer in two ways; first, if he is under pressure to reduce costs, he may attempt to minimize the amount of thermoplastic material in a certain area of the part, i.e., wall section. Secondly, he may determine that perhaps being non-critical, a particular area or rib could be designed below this minimum thickness and still maintain the requisite strength. Another example would be the vacuum-formed part in which a relatively important area, strength-wise, exists at the point of deepest draw.

Thermoplastic Processing

In further discussing the effect of thermoplastic processing a common misconception should be corrected. It suggests that there is unchanging uniformity in thermoplastic materials through a heating-cooling cycle. This error is undoubtedly basically responsible for many of the misapplications of these materials. However, this misapplication should in many cases be more properly labelled misfabrication.

In most all fabrication procedures on thermoplastic materials, the basic material is either an extruded pellet or a fine powdered form of the polymer. This material is heated in one or more successive chambers. Heat energy is supplied either externally or is generated within the mass by friction, as in an extruder. As the material becomes less viscous by the absorption of more energy, it reaches a state where it can be formed into the shape desired by any of the thermoforming processes. In an extrusion-type process or injection molding of thermoplastics into parts having precise dimensional requirements, the necessary force is appreciable.

The inter-relationships of the heat content of each incremental particle of the thermoplastic melt and the changing value of these applied forces as this viscous material flows through the process machine becomes then the ultimate factor.

Fabrication Effect Upon Properties

During plastic flow, low flow velocities permit loss of heat to surrounding surfaces, viscosity becomes greater requiring greater force, shear forces within the viscous polymer mass become most destructive and all the time heat is being lost and the plastics material becomes rigid. Yet these shear forces are still in existence. The same effect occurs when insufficient heat is applied to the plastics melt, viscosity is too high for efficient flow and a highly stressed part results. A parallel condition to this improper plastics flow is the well-known molecular degradation obtained by excessive heating. Proper fabrication of thermoplastics then depends on treading the "straight and narrow path" between these two fundamental, yet not-too-widely distant, extremes. In injection molding, proper plasticizing and high-speed injection can accomplish this function.

In applying thermoplastic materials, the engineer or designer must have assurance that the part will be fabricated properly with respect to adequacy of plasticizing and viscous flow requirements.

Cost Elements

The injection molder, in quoting this part, has many things to consider, not the least of which are his ability to produce a fast plastics "melt" and to fill the mold rapidly. He contemplates producing the part on a $6/hr. machine at the rate of 200 pieces /hr. This provides him with a 3 cent labor and burden cost per piece. The average plastics cost for this part might be about 15 or 16 cents (4 oz. of acrylic). It can be seen that the labor and burden cost will be the smallest portion of the piece part cost and the larger the part, the smaller the labor and burden portion becomes percentage-wise. Thus, if it is found after the tools are built that the part will only "run" properly on an $8/hr. machine and the production rate is limited to 160 pieces/hr., the labor and burden cost rises to 5 cents. This extra cost factor is quite a substantial increase over the original estimate.

There are several ways in which this extra cost can be eliminated. But all of these items involve elements of the fabrication process that bear directly on the quality of the plasticizing. The molder does not want to lose 2 cents on this part. He may put it on the small machine and run it beyond capacity and then ship parts at the quoted figure. Who is to blame when they fail in use? The molder, the purchasing agent, or the designer? The point is that there is a proper price and rate of molding for each part, and the designer must know these factors well. By this simple example, it becomes obvious that all elements of the designing-purchasing-production chain have a direct effect upon the satisfactory acceptance of thermoplastic parts.

Historical Background of Plastics at Ford Motor Company

John Mickey

Engineer-Adhesives and Plastics
Non Metallic Section
Ford Motor Company
Detroit, Michigan

The Ford Motor Company has been extremely interested in the development and practical application of plastics. This interest dates back to the compression molded plastics horn button used on the Model "T".

Company Developments

The following account outlines the developments that have been pursued by this company.

In 1928 distributor assembly parts of the model "A" Ford were compression molded with phenolics.

In 1937 ignition coil cases were compression molded of "soy bean" plastics. During the same period (1937-1938) door handle and window regulator escutcheons were injection molded of a thermoplastic cellulose butyrate acetate (*Figure 1*).

In 1938 a project was instituted to develop an all plastics automobile. This resulted in the successful completion of a prototype in 1941. With the exception of frame components

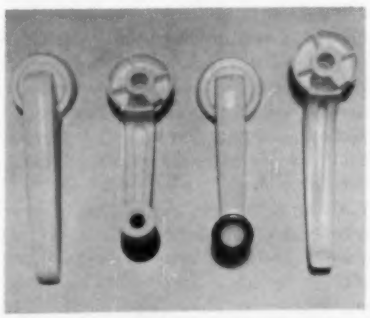


Figure 1. Thermoplastic door handles and window regulator

Figure 2. Polyester fiber glass station wagon exterior trim parts

and other necessarily structural elements, the car was plastic. Windows were of acrylic and trim was acetate butyrate. This was the first all plastics automobile built in the United States.

After World War II (1946), a development program was begun which resulted in the fabrication and field testing of a polyester fiberglass tail gate for the 1947 Ford station wagon. The part showed superiority over metal in the field tests. Although never introduced to production, this part did serve to establish criteria around which specifications for polyester glass fiber parts could be written. These specifications are in use today. The final result was manifested in the 1954 Ford and Mercury station wagon exterior trim parts, (*Figure 2*).

During this period, in order to fully evaluate the versatility of the material, bumpers, grill sections and seat frames were "built" of polyester fiberglass type materials. In 1953 the feasibility of a plastics production part was reflected in the "hard top" of all two passenger "Thunderbirds".

From 1947 to 1961, numerous other areas of use previously relegated to other materials have been resolved to plastics. The first functional continuous use application of nylon came into being in the speedometer gear. Since then this material has been used for door striker plates and seat bumpers, to mention a few applications, with a great deal of success.

Earlier than 1953 arm rest frames were injection molded of thermoplastic materials. Now they are standard with almost all manufacturers.

Although it is generally known, it would serve well to recognize that practically all decorative medallions are made of acrylic and decorated on the second surface. This technique provides exceptional longevity of finish due to the protective attribute of plastic over less stable materials.

Tail light lenses, due to the necessity for complex three dimension configuration and incorporation of light control facilities, are now as generic to acrylics as drinking glasses are to glass.

Since plastics raw material suppliers have been contributing even more time and development to honest design assistance, within the automotive industry, newer and more interesting material uses have been coming forth. Some examples are:

1. Injection molded vinyl sleeves—injection molded and extruded trim elements.
2. 1959 Ford seat side shields—injection molded of linear polyethylene.
3. 1961 Falcon station wagon wheel cover—injection molded of linear polyethylene.
4. 1961 "Econoline" door handles and window regulator arms—injection molded of acetal.
5. Ford accelerator pedal of polypropylene.

Specifying and Testing Plastics Materials at Chrysler Corp.

W. J. Simpson

Rubber & Plastics Laboratory
Engineering Division
Chrysler Corporation
Detroit, Michigan

Properties and testing methods described in Chrysler Plastics Specifications have two purposes:

1. To check parts and materials for necessary application requirements.
2. To outline characteristics of a material well enough to enable designers or materials engineers to choose materials intelligently for each application.

Because of the overall structure of the plastics industry, the system used to specify plastics differs somewhat from the systems used to specify other materials such as rubber, metals, cements and sealers. Plastics parts and components purchased by automotive companies are manufactured by small and medium size molders, extruders and other types of fabricators who usually do not compound or manufacture the raw materials (manufactured by larger chemical companies) used in their production processes. Because of this situation three types of documents are used at Chrysler to specify plastics parts or components, namely:

1. Material Standard
2. Chrysler Plastics Numbers
3. Engineering Approved Source

Material Standard

The Material Standard classifies plastics raw materials and defines their essential properties. Special properties such as color and friction characteristics are not covered in the Material Standard, but are controlled by the Plastics Number designation. The Material Standard defines basic plastics materials such as polypropylene, cellulose or acetate butyrate or groups of materials having common properties, such as various vinyl plastisol or polyester "pre-mix type" compounds. These are not product specifications.

Chrysler Plastics Number

A Chrysler Plastics Number (CPN) is a list of specially approved *materials* and their manufacturers. It refers to the basic Material Standard and serves to pinpoint or "tie down" properties which are not described in the requirements of the Material Standard. The use of the Plastics Number evolved originally from a need to create a system to define materials of different color covered by the same Material Standard. During 1940 glove box doors and instrument panel knobs were released in cellulosic plastics. Later other special properties were included, such as impact properties, acoustical characteristics, some electrical properties and processes and adhesion requirements (adaptability to adhesives).

In almost all cases, the basic Material Standard sufficiently defines the requirements of the material so that tooling of the part or component involved can be started. The addition of properties defined by the CPN usually does not affect tooling considerations (shrinkage and mold design).

Thus, drawings for plastics parts or components normally contain not only the Material Standard designation but also a Plastics Number, which is the prefix CPN followed by a numerical designation. For instance, the material designation on a plastics steering wheel drawing may list MS-DB12 and CPN-99999.

Approved Source List

The Engineering Approved Source List for plastics materials is of two types. The Approved Source Lists published internally under the Material Standard Numbers are a compilation of qualified and approved fabricating vendors for the designated basic material, broken down to show molders, extruders, vacuum formers and decorating sources to indicate the types of fabrication involved and groupings.

Table 1. Maximum Useable Temperatures of Typical Types of Plastics Materials*

Type of Plastic	Max. Recommended Continuous Service Temperature	Linear Thermal Expansion** (In./°C x 10^{-5})
Phenolic Molding Compounds	250°F. to 425°F. Dependent on Compound	3-4
Alkyd Molding Compounds	Approx. 400°F.	3-4
Polyester Premix Compounds	250°F. to 350°F.	2
Acrylic Plastics—		
(Heat resistant grade used in Lenses)	185°F. to 200°F.	9
Polyethylene—		
Low Density	140°F. to 175°F.	15-30
Medium Density	160°F. to 200°F.	15-30
High Density	Approx. 200°F.	15-30
Teflon—		
TFE	500°F.	5.5
FEP	390°F.	7
Vinyl—		
Non-rigid	130°F. to 165°F.	-
Rigid	150°F. to 160°F.	5-12
Polystyrene—		
General Purpose	150°F. to 165°F.	6-8
Improved Heat Resist.	160°F. to 180°F.	6-8
Cellulose Acetate Butyrate—		
Medium	Approx. 180°F. to 190°F.	11-17
Soft	Approx. 180°F. to 190°F.	11-17
Nylon—		
Type 6,6	250°F.	10
Type 6	230°F.	8.3
ABS Plastics	200°F. to 210°F.	8-10
Acetal Resin	250°F.	8

* The recommended temperatures are based on combined experience of the members of the Rubber and Plastics Laboratory staff. It is assumed that products made from these materials will be fabricated properly to obtain optimum properties.
** For purposes of comparison, the thermal expansion of steel used in automotive bodies can be considered .8 to 1.2 x 10^{-5}/°C.

The second type of Approved Source List is that listing the approved vendors and materials for each Plastics Number. The Approved Source List for every Plastics Number must contain at least one approved vendor and material.

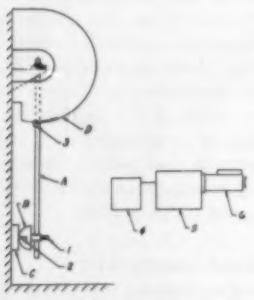


Figure 1. Instrument panel impact tester—Legend.
A—Pendulum
B—Hemispherical impact head
C—Anvil or specimen holer
D—Arc calibrated in degrees
1—Accelerometer
2—Pressure transducer
3—Triggering device (photocell)
4—Amplifier system
5—Dual Beam Oscillograph (cathode ray)
6—Recording Device (Poloroid camera)

Testing

When specifying requirements for plastics components, routine and standard test methods (tensile strength, hardness, impact resistance, common aging and light exposure tests) are used as much as possible for the testing of plastics parts to control uniformity and to provide basic data for qualifying fabricating vendors.

Plastics products require specialized testing methods because of the characteristics of materials and processes used to make them.

A testing method which combines both high and low temperature tests has proven to be very valuable. This is known as the hot-cold cycle test. As far as possible, ASTM D-756 (outlined in more detail in Laboratory Procedure 463-DD-8-01) is followed. *Table 1* shows maximum useable temperature limits of several plastic materials.

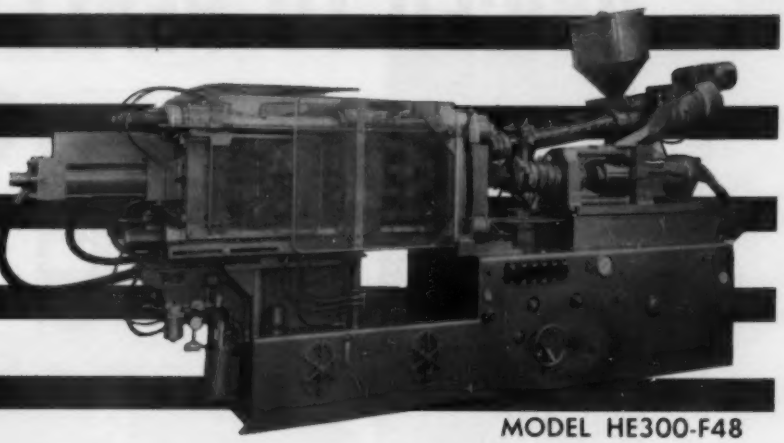
Special procedures developed for crash padding illustrate use of specialized testing needed so often for plastic products. Concern for the safety of car passengers during sudden stops, collisions and other accidents has led to the use of safety items such as padding and seat belts. To test the effectiveness of safety pad materials and construction, tests to measure energy absorption characteristics were devised. Based on the original efforts made at the Cornell Aeronautical Laboratory, the equipment illustrated schematically in *Figure 1* was developed.

The following physical properties may be determined with the aid of this equipment; energy absorption; resilience; peak pressure at impact (the test evaluates rigidity, cell behaviour, effectiveness of thickness); depth of penetration and rate of change of deceleration.

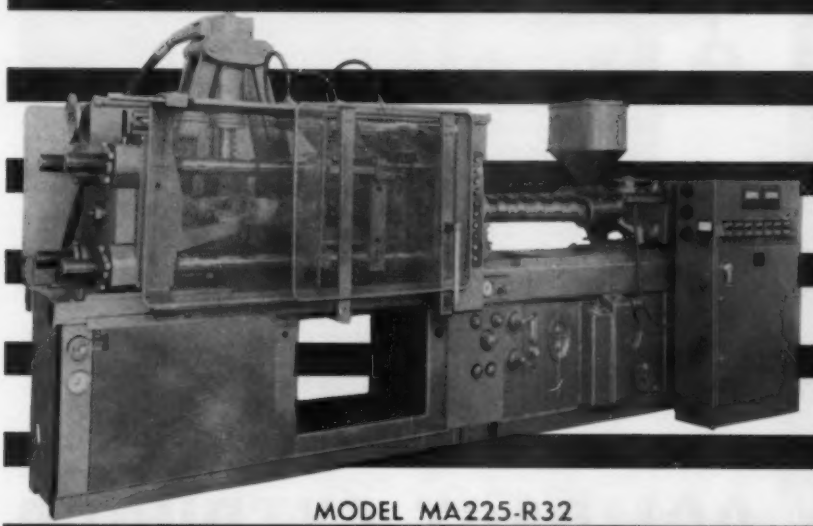
The combination of these characteristics serves as the basis for designing energy absorbing components. In addition the following two tests may be performed.

Shrinkage which takes place over 160°F is tested at temperatures up to 190°F. "Fog" which is a result of evaporation of volatile plasticizers is tested for by subjecting a sample of material to a 500 watt infra-red lamp at 190°F for 16 hours.

NOW— SCREW-TYPE PLASTIFYING



MODEL HE300-F48



MODEL MA225-R32

ON IMPCO INJECTION MOLDING MACHINES

To meet the needs of the plastic molding industry, Impco offers a complete line of screw plastifiers. Various design adaptions for this type of plastifying are now available on all of our machine models. Bulletins describing these adaptions as applied to Impco 175, 225, 275, 300 and 450 ton clamp models are on hand. Send for them today. We will be happy to discuss these and other significant improvements with you.

IMPCO®

IMPROVED MACHINERY INC.

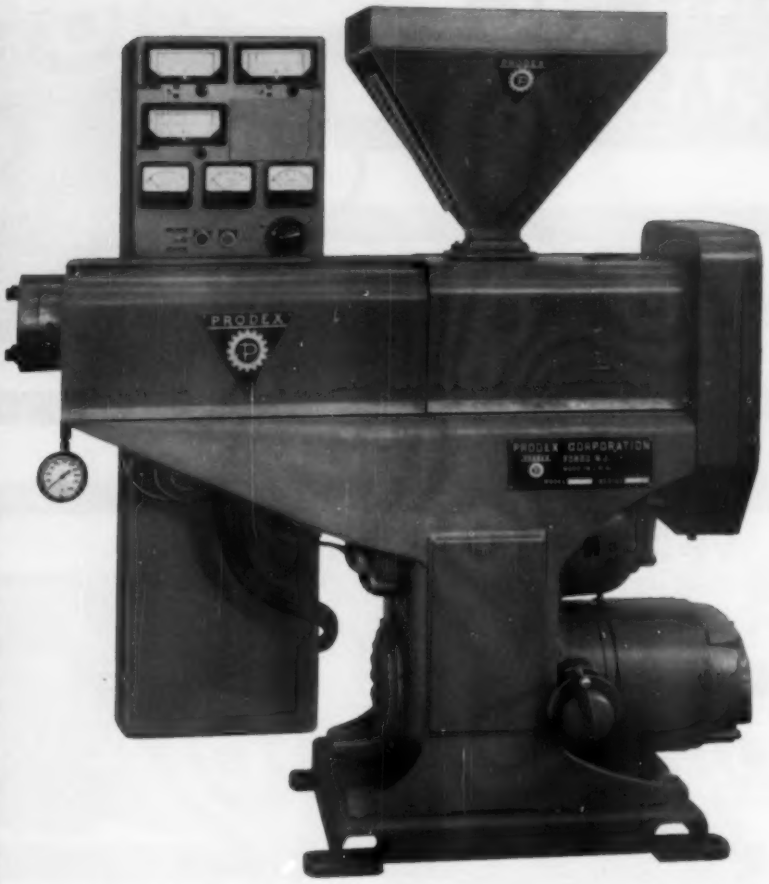
NASHUA, NEW HAMPSHIRE

IN CANADA: SHERBROOKE MACHINERIES LIMITED, SHERBROOKE, QUEBEC
IN EUROPE: SUNDS VERKSTADER AB, SUNDSBRUK, SWEDEN

PRICED TO REALLY COMPETE

OUTPUT RATES:
50—150 lbs/hr

L/D RATIOS:
20:1 and 24:1



the new

PRODEX COMPACT EXTRUDER

QUALITY FEATURES INCLUDE

- Heavy integral machine/motor base requiring half the space needed before.
- Alloy steel screw. Screw flights hard surfaced with Stellite (not flame hardened). They maintain their hardness, Rockwell C55, through highest extrusion temperatures.
- One-piece heavy wall cylinder Xaloy-lined.
- Thrust assembly with self-aligning spherical roller thrust bearing, large inspection window and circulating oil lubrication system.
- Large rectangular feed opening.
- Swing gate for easy die mounting.
- Automatic temperature control.
- Efficient air cooling.
- Full instrumentation, including screw speed indicator, melt temperature indicator and motor load ammeter.
- Continuously adjustable speed range 4.5 to 1.
- Completely prewired ready to run.

See the Prodex Compact perform with your own materials in our Customer Service Laboratory. Phone or write for an appointment or literature.

PRODEX
—in design and performance
ALWAYS A YEAR AHEAD

PRODEX CORPORATION
FORDS, NEW JERSEY • Phone: HILLCREST 2-2800

H. S. Malby,
A. N. Ciarlone, C. M. Greene

Celanese Polymer Co.

SPEAKING OF EXTRUSION

Production Problems in Blow Molding

Worried about production problems in blow molding? This article lists the main troubles encountered and offers some suggestions for their elimination. Problems occurring during parison formation and during and after blowing are discussed

With the growing popularity of blow molding there is a need for the description, analysis, and cure for some of the more common troubles that arise during the process. This article will be confined to extrusion blow molding.

The basic principle of blow molding is fairly simple. A tube (commonly called a parison) is made by screw extrusion. This tube or parison after forming is immediately surrounded by the two halves of a mold. As the mold closes, either one end or both ends of the parison are pinched, and air pressure is introduced either through the open end of the parison or if both ends are pinched through a needle or some other device.

There are three major controlling areas of this blow molding process.

1. The extruder
2. The head (extrusion die and manifold if present)
3. The blow molding machine

The extruder should have adequate screw motor power, proper temperature controls and a suitable screw design for the various materials to be utilized. As a general rule the extruder should have a minimum L/D (length over diameter) ratio of 16:1 and a channel depth ratio of 3.5:1 for polyethylene, for example.

The blow molding head must have adequate temperature controls, heat capacity and streamline flow to prevent stagnation of the molten resin, and adequate adjustment for proper centering of the die.

Figure 1. Blow molding problem —doughnut formation where the parison spreads outwards and adheres to the face

Interested in a reprint?

Write, Editor, SPE Journal, 65 Prospect St., Stamford, Conn.

The blow molding machine should be of proper size to handle anticipated parts, have facility for mold heating and cooling, and contain proper controls for the various production cycles that may be desired.

Blow Molding Problems

Troubles that may be encountered in the blow molding process may be classified under the three following headings: 1) Problems Involving Formation of the Parison, 2) Problems occurring During Blow Molding and 3) Problems Occurring after Molding.

Problems Involving Formation of the Parison

Curl of parison—The parison moves or curls from the vertical plane.

Rough parison—This is evidenced by a grainy or rope-like appearance on the surface of the tube.
Doughnut formation—This describes the appearance of the parison when it spreads outward and adheres to the face of the die. (*Figure 1*)
Contamination—Contaminants are usually visible in the parison as specks differing in color.
Neck down—Excessive stretching of the parison evident by a thickening of the parison at the bottom and a thinning at the upper end adjacent to the die.
Die and/or weld lines—Lines in the parison parallel to its axis and differing in opacity from the base material are commonly known as die lines or weld lines depending on their origin. (*Figure 2*)

Figure 2. Die and weld lines. Lines of different opacity are parallel to the axis of the parison

Problems Occurring During the Blowing Phase

No blow—This describes the case where a part fails to blow up to the shape of the mold.
Blow out—A blow out occurs when the air blows out a portion of the part wall thus failing to completely form a part.

Problems Occurring After Molding

Poor surfaces—Poor delineation and surface blemish as demonstrated by an orange peel surface or "pock marks". (*Figure 3*)
Indentation at parting line—This indentation is visible both at parting lines and at various radii such as flutes, shoulder, chine, etc. Cutting the part will show a definite thinness at this point. (*Figure 4*)
Warped tops and bottoms—These are self evident. (*Figure 5*)
Lack of tail control—Lack of tail control in the pinch-off area is evident when the tail rolls over and adheres to the molded part.
General post molding distortion—This occurs after the molded part has been standing for a period of time after the blow molding operation.

Figure 3. Poor surface sample

Suggested Remedies

Problems of the Parison Formation Period:

Curl of parison—Parison curl is caused by non-uniform wall thickness in the parison. The direction of the curl is toward the thin area. This can be corrected by adjustment of the die bolts, or in some cases by a check of the heat history of the parison. Non-uniform heating will cause thick and thin areas in the parison. Occasionally the heaters in the manifold and head areas either have poor contact with the surface or defective heating elements. When this occurs, a band of hot and cold areas will result. This creates, in the area of excessive heat, a thickening of the parison wall because of reduced viscosity. In the case of a cold area, a thinning will result because of the increased viscosity.
Rough parison—A rough parison may be caused by too low a melt temperature or melt fracture. The melt temperature should be fixed or set by adjusting the extruder heat and speed as well as the heat applied to the head. These should normally be such that the peak temperature is at the forward end of the screw with a slight drop to the die opening. This temperature drop should be in the neighborhood of 10°-15°F. The proper or useful melt temperature will be that which is high enough to eliminate grain on the surface of the surface of the parison and at the same time yields a minimum neck down. Melt fracture occurs when the resin is extruded in a critical shear rate range. Here again, higher heats will usually help. If higher heats fail to clear up the problem then the die should be examined for overly sharp angles of entry. The angle of entry from body to land area should not exceed 20°.
Doughnut formation—A doughnut formation occurs when the mandrel has not reached an equilibrium temperature with the rest of the blowing head. The remedy is to allow more time for heat-up so that the mandrel is the same temperature as the die.
Contamination—Contaminants in the parison are usually a result of degraded material in the system or poor housekeeping. Housekeeping is a matter of common sense. Good housekeeping needs proper control and storage of scrap, the minimizing of dust and dirt in the plant atmosphere especially in the area of the blow molding machines. The storage of resins in uncovered containers or bags should be avoided. Degraded material results from improper start-up or shut-down procedures. To start up an extrusion machine correctly, one should ascertain that the extruder barrel is clean of all foreign resins, oil, and lubricating grease. The barrel temperatures should be set at the temperature advised for the material and with the extruder empty. In the case of low density polyethylene for example the barrel temperatures should be 300°-325°F

Figure 4. Indentation at parting line. The part is thinner at these points

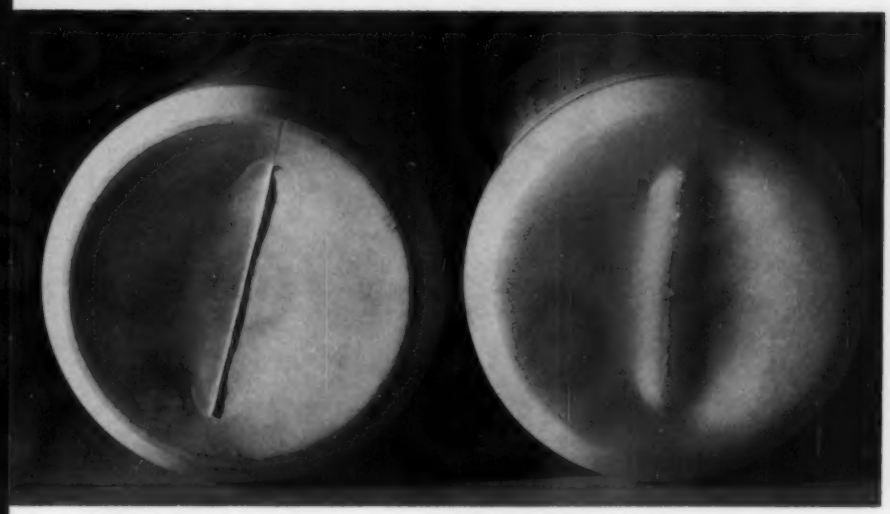


Figure 5. Warped top and bottom samples

and with a high density polyethylene they should be 375°-400°F. When the temperatures have reached an equilibrium, the resins should be charged to the extruder. Proper operating temperature can then be determined by experimentation. When shutting down the extruder, the barrel temperatures should be lowered with the extruder screw running. When barrel temperatures have reached the melting point of the resin being used, the extruder can then be shut off. Under no conditions should the extruder screw be stopped for periods in excess of ten minutes when there is material residing in the machine at normal operating temperatures.

Another cause of contaminants in the parison is poor flow design causing a stagnation or hang up of material. The most common area of hang up is in the head. This area should be checked for streamline flow throughout. When it is not possible to remove the area of stagnation by design changes, it is often possible to install a bleeder plug in this area. By this method, the material that would normally stagnate is diverted from the main stream of polymer flow.

Neck down—Parison neck down can result from several causes:

1. Improper material selection
2. Melt temperature too high
3. Cycle too slow

Improper material selection results when polyethylene of too low density or too high melt index is used for a large parison size. In the case of detergent containers, a density of 0.945-0.950 and a melt of from 0.15 to 0.30 is generally found to be acceptable. Toys are successfully blown in 0.96 density with a melt index as high as 1.5. Actual resin selection will depend on experimentation. The basic problem is one of tensile strength of the plastic in the melt state. These properties differ both with the type of plastic and with the grades within a given type. The effects of neck down are to some extent overcome if the plastic has a good elasticity. In this case, it will shrink back and recover during parison formation that thickness lost by the necking down action. Too high melt temperature will result in parison neck down or parison stretch out.

A screw speed that is too slow will create an unduly long time for parison formation causing the full effect of gravity developing a parison neck down condition. The obvious remedy is to increase screw speed.

Die and/or weld lines—Die lines and weld lines in the parison may be caused by a combination of different density and melt index polyethylenes, by nicks or scratches in the die or mandrel, or by impeding the resin flow somewhere in the die head. A melt index spread of 3:1 in a blend has been found to be about the maximum.

Allowance for complete bleed-out of material before charging machine with a new material will usually prevent mixtures of non-compatible plastics. Proper maintenance and care will prevent the occurrence of nicks and scores in the die and mandrel. As discussed previously, streamline flow through the head will help prevent stagnation and hang-up of material.

Suggested Cures for Blowing Phase Problems

No blow—When a part does not "blow up" or is not formed the causes might be:

(a) Air supply not hooked up
(b) Air supply pinched off
(c) Pinch-off areas too sharp or not tight enough

Solutions to (a) and (b) are self evident. When a pinch-off is too sharp it creates a thin area that will not retain the blowing pressure. When the pinch area is not tight enough the blowing air is not contained and the part does not blow. Both these problems can be eliminated by proper mold design.

The pinch-off areas at the top and bottom of the mold where the parison is pinched together to make a seal are subject to a disproportionately great amount of the wear. Besides making an air-tight seal, these pinch-off portions of the mold land are usually designed to cut nearly through the excess parison to simplify its removal from the finished product. Because of this, the mold lands at the pinch-off area are often made narrower. This combination of greater wear on a smaller surface makes the use of replaceable pinch-off land inserts advisable in many cases.

All molds should provide for maintaining a uniform temperature. Temperature controlled coolant may be circulated through a series of water channels bored into each mold half or through copper tubing cast into the molds. In some cases, the back of the mold may be cored or "hogged" out and covered with a gasketed plate to which a water inlet and outlet are fixed.

High density aluminum cast molds or those machined from bar stock may be cooled employing this system. Some cast molds are relatively porous and cooling in this manner may result in a "weeping" or leaking mold.

The most critical areas of temperature control are the neck and pinch-off areas (top and bottom of the molds) where the plastic mass is thickest. These areas have more heat to be removed. Larger diameter channels in these areas with more coolant circulating tend to equalize the rate of heat transfer of these critical areas.

KILL STATIC WITH A GUN!

Simco Ionizing Air Guns will put an end to static woes in any finishing operation! Plastic parts are blown clean, while being neutralized, so that dust, dirt and lint are *completely* removed and will not be reattracted! This new electronic air gun is safe, easy to use, and *guaranteed* effective! Write for facts.

the SIMCO company
920 Walnut Street, Lansdale, Pa.

Controlled mold temperatures shorten the blowing cycle and renders more uniform surfaces on products produced.

On occasion we have found the molds move after closing and just as the air enters. This action will thin the plastic adjacent to the pinch-off and cause a "no blow".

Blow out—A blow out of a part may be caused by several reasons:

1. Mold separation
2. Part not sufficiently cooled
3. Improper design in the parting line

Mold separation usually occurs when the part being blown is too large for the capacity of the blow molding machine. This occurs because the clamping pressure on the molds is too low and cannot contain the blowing pressure. Sometimes, larger clamp pressure can be attained by installing bigger pistons but the usual solution is to restrict part size or install larger machines.

Another cause of part blow out is opening of the blowing molds before the part is fully cooled causing a rupture, usually at a parting line. The simplest solution is to allow longer cooling of the part or increase the rate of mold cooling assuming the use of minimum blowing pressure.

3. Post Molding Difficulties and Suggested Solutions:

Poor surfaces—Poor delineation and surface blemishes can be caused by:

1. Improper melt temperature
2. Improper mold temperature
3. Improper mold finish
4. Inadequate blow pressure

Improper low melt temperature will cause the blown part to become too cold for proper forming and give a "pocked" surface because of insufficient pressure of the plastic against the mold surface. The answer can only be attained by experimentation.

A low mold temperature will cause a pocked or orange peel surface. Too hot a mold surface will prevent complete forming of the piece or cause an unreasonably long cycle.

A rough mold finish will produce rough parts. A too smooth mold finish will entrap air and produce surface pocking. Usual mold finish procedures call for vapor honing the mold surfaces. Inadequate blowing pressure does not force out the entrapped air in the mold before the resin sets up and this will also result in poor delineation of the cavity surfaces.

Indentation at parting line—Indentations at the parting line, at the shoulder, chines, or flutes are caused by using too low a mold temperature. Raising the mold temperature will usually eliminate this problem.

Warped Tops and Bottoms—Warped or distorted tops and bottoms are usually caused by removing the blown parts before they are sufficiently cooled. This may often require special cooling of these areas in the mold to achieve desired cycle time.

Lack of Tail Control—Lack of tail control occurs when the parison is too long creating an unwieldy and excessively long tail piece. Usual procedure is to shorten blowing cycle so that the parison is pinched off faster.

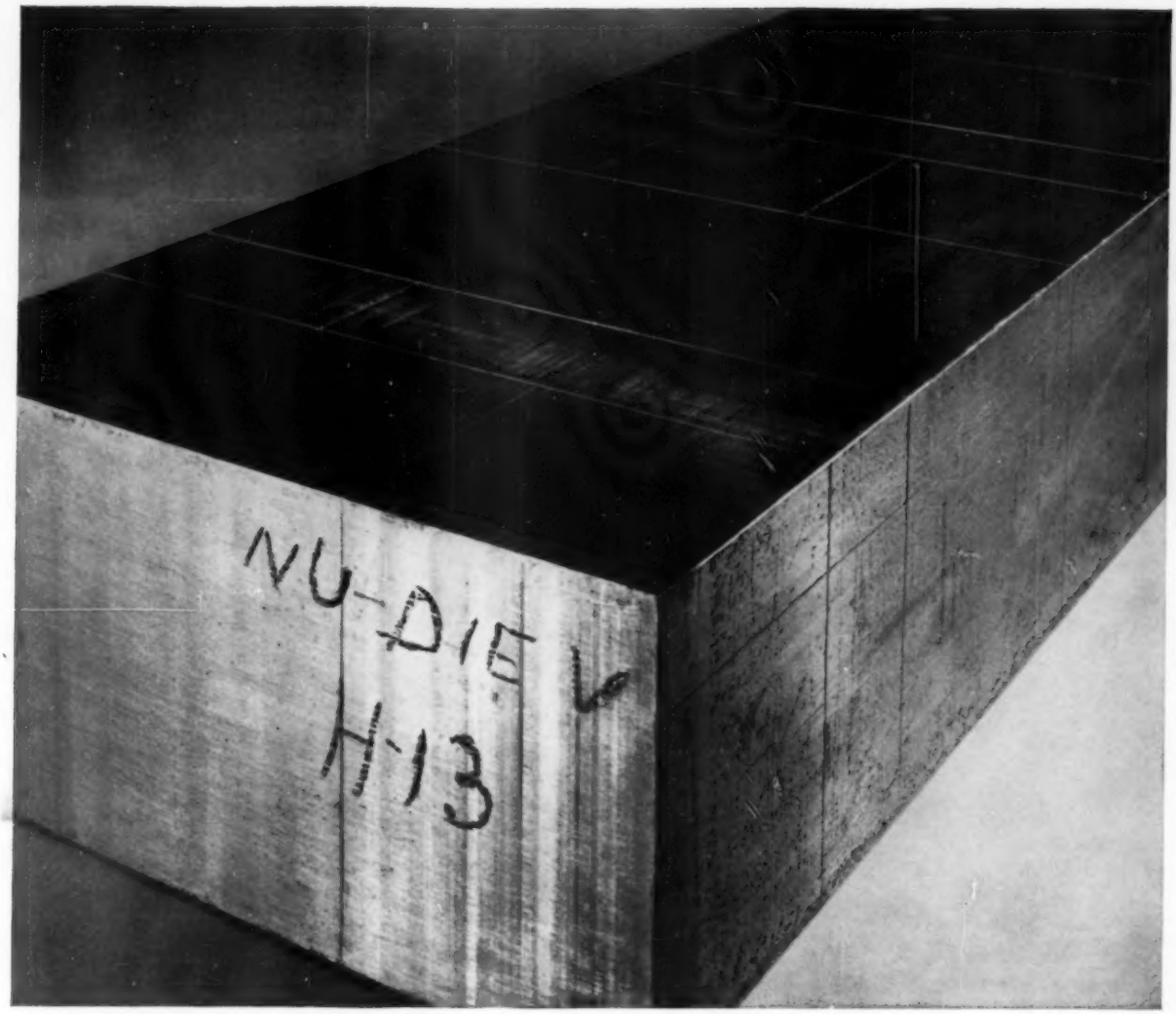
General Post Molding Distortion—Post molding distortion occurs when a part has not been cooled long enough before removal from the mold. It also occurs when the blown piece has a heavy wall section that has to be post cooled in a cooling device. An example of this is a cooling jig wherein the part is firmly affixed with a clamp and then partially submerged in a water tank.

Conclusions

It is obvious that all possible difficulties have not been discussed, but we hope this paper will give an insight into the cause and solution of some of the more common problems experienced in blow molding. The proper application of these solutions will, of course, involve compromises as the solution to one problem may be contrary to some other problem Only by carefully balancing one condition against another throughout the system, will it be possible to arrive at the optimum conditions for production. Ideally the limiting factor in a blow molding operation should be the cooling rate of the part in the mold. Heat can only be removed from a given part in relation to its surface area. When this removal is at its peak no further speed can be attained without changing plastic or design. Once this time period is established every effort should be made to cause the rest of the extrusion and blowing system to conform. When this has been achieved then the system will be operating at peak efficiency.

—— ■ ——

Edited by **Bruce H. Maddock**
Union Carbide Plastics Co.



every surface—die quality . . .

because **DENSIFIED** NU-DIE V is more uniform throughout the cross section

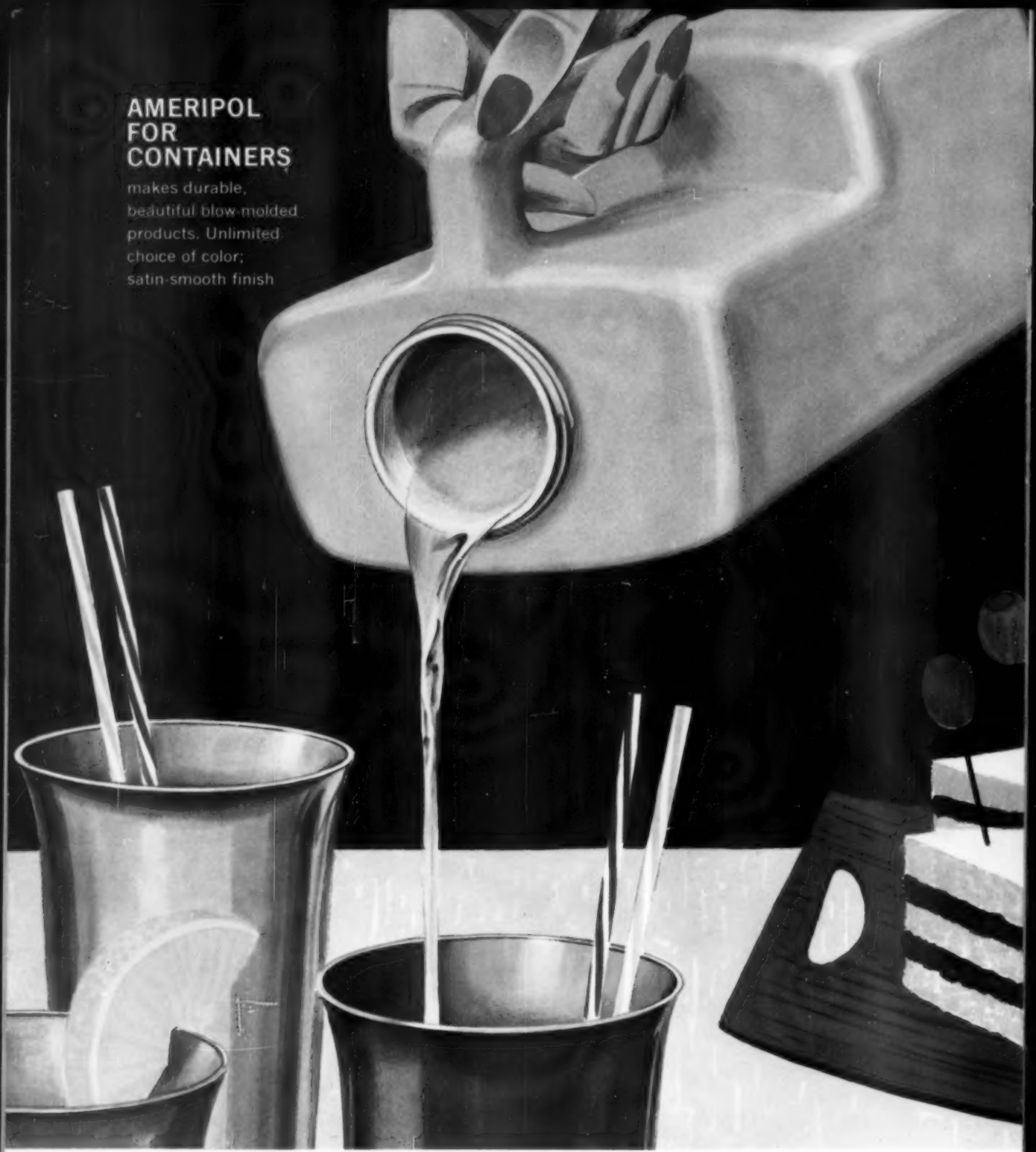
A new Crucible process-DENSIFYING-sets NU-DIEV® apart from other H13 steels. *Densifying* benefits you in four major ways: *1.* It permits you to use larger sections with greater assurance of sound centers. *2.* It enables you to produce dies with even better finishes. *3.* It makes your dies less susceptible to washing and cracking. *4.* It also speeds deliveries of your die blocks because NU-DIE V now eliminates the need to specify individual forgings.

The DENSIFYING process, developed by Crucible, involves more than the normal consideration of steel analyses and amount of reduction. It includes careful appraisals of ingot size and shape, processing temperature control, and special methods of reduction. Only Crucible successfully combines all these techniques to produce this more uniformly *dense* Type H13 steel.

For more information on DENSIFIED NU-DIE V or CSM 2 die steels, call your local Crucible steel center.

Crucible Steel Company of America, Four Gateway Center, P. O. Box 88, Pittsburgh 30, Pennsylvania.

CRUCIBLE STEEL COMPANY OF AMERICA



Look into **AMERIPOL**–the strong, strong

Ameripol is the new high-density polyethylene that offers exceptional physical properties — yet Goodrich-Gulf makes it so that it is easy to process. This means that with Ameripol you can substantially upgrade product quality without incurring higher production costs. No processing difficulties . . . use standard equipment. Finished products are easily machined, grooved, or punched. Investigate Ameripol for a *strong* polyethylene that is *easy* to process.

Call Goodrich-Gulf — Ameripol Technical Data File has the complete story on physical properties and specifications. And Goodrich-Gulf Technical Service engineers can help you with application. Write today for information.

AMERIPOL FOR PIPE

excellent impact strength and stress-crack resistance make a superior plastic pipe — yet easy to extrude on standard equipment

AMERIPOL FOR INSULATION

extrudes easily, yet provides a tough, temperature-resistant coating with excellent dielectric properties

polyethylene that is easy, easy to process

CLEVELAND:
1717 East Ninth Street
Phone: **TOwer 1-3500**

NEW YORK:
200 East 42nd Street
Phone: **MUrray Hill 7-4255**

Goodrich-Gulf Chemicals, Inc.

THE ONE TO WATCH FOR NEW DEVELOPMENTS

Why the MOLD DESIGNER

talks D-M-E ECONOMY to the Mold Maker and Molder

Interchangeability of D-M-E Standard Mold Bases Leads to Extra Savings!

Specifying D-M-E Standard Mold Bases and component parts reduces mold cost, saves time, and provides an unlimited variety of plastic mold assemblies.

D-M-E standard components are fully interchangeable: Replacements can be made without special fitting or reworking. Cavity plates and components can easily and quickly be removed and replaced in perfect alignment.

Whether for injection or compression molding, D-M-E Standard Mold Bases enable you to work with greater flexibility by providing a selection of over 7,000 cataloged mold base combinations! And D-M-E Master Layouts enable designers to devote more time to cavity layout.

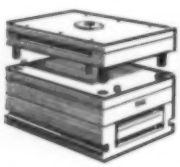
MOLD MAKER: D-M-E first-quality carbon or alloy steel assures easier and more reliable machining. And D-M-E Standard Mold Bases have exclusive built-in features at standard cost: surfaces ground flat and square; patented tubular dowels; one-piece ejector housing; stop pins welded to ejector plate; 33 sizes from 9⅞" x 8" to 23¾" x 35½".

MOLDER: D-M-E Standard Mold Bases and components reduce maintenance. They are carried *in stock* at your local D-M-E Branch ready for quick delivery. You eliminate waiting, cut downtime, reduce your inventory and maintain production schedules. With D-M-E you get supplies when you need them from a single reliable source!

FREE CATALOG

Write today for your 242-page D-M-E Catalog of Standard Mold Bases and Mold Makers' Supplies. No cost, no obligation.

61-A-P



DME

DETROIT MOLD ENGINEERING COMPANY

6686 E. McNichols Road — Detroit 12, Michigan — TWinbrook 1-1300

Chicago • Hillside, N. J. • Los Angeles • D-M-E Corp., Cleveland, Dayton
D-M-E of Canada, Inc., Toronto

Injection and Compression Mold Bases • Injection Unit Molds • Cavity Retainer Sets • Mold Plates • Ejector and Core Pins
Ejector Sleeves • Leader Pins and Bushings • Sprue Bushings • Moldmakers' Tools and Supplies

John A. Kavanagh

Standard Tool Company

MOLDMAKING

The New Mold, Its Problems and Some Solutions

This article describes some of the problems that might be encountered with a new mold before it is trouble-free and producing parts satisfactorily in a production run

Rarely can a mold be received from a mold maker and immediately be placed in the machine and put to work satisfactorily. It does happen, but with the multiple of materials available today and the complications presented by a variety of machines, high-speed operation, automation, and product designs, the molder regardless of the preparation, can anticipate adjustments and changes. A check of the important features that follow will be well worth the time.

Gating

This is the most important part of the mold layout; it should be given the most consideration bearing in mind not only its particular location but the type that is proposed. There is an edge-gate, submarine gate, center-gate by means of a 3-plate mold, hot runner or runnerless mold gate. The advantages of the latter three types of gating, all gating into the center of a part, are many, providing that the item being molded is such that center gating is possible and in some instances definitely necessary. Variations in cross section of a part, especially where there is a heavy section on the rim or edge, a center gate, makes it possible to fill without trapping gas. The center gate in a large projected area cuts the required distance of flow of the material in half in comparison to the edge gate. This tends to eliminate strains that would not only produce an inherent weakness in the casting but assist in producing a flat casting. A series of gates in the bottom of large parts—houseware items, boxes, trays, etc., when molded in linear polyethylene or polypropylene, assist to produce good pieces.

The hot runner mold or runnerless mold has the same advantages along with other advantages such as short cycle time, easy material handling and automation. Hot runner construction varies and multi-nozzle construction offered by many machines is a form of hot runner molding.

Venting

Physical dimensions of the cavity, type of material, and even the make and model machine have varying degrees of effect on venting. The methods, of course, vary. The simplest and most widely used in a plain vent groove on the parting line, generally .0015" deep, width of a surface grinder wheel. The use of poppet valves, the venting by means of flats on knockout pins and inserts are other methods. The location of the gate and type of gate into the cavity should be carefully considered in light of the venting problem, which will be encountered. Venting and flash are to a degree tied together. If a mold is not properly vented and excessive pressure is required to fill the cavities, the result will generally be flashing of the cavities as actually the mold opens up to allow the gas and air to escape resulting in an overflow of the cavities which is flash. Some flash is, of course, caused by mismatch or miter. Miter can be easy to differentiate from actual flash. However, even with a properly vented mold there are other reasons that would cause flash. An improper support in a holder under the cavities can result in flash depending upon the pressure of the injected material. Small molds set in a relatively large machine can actually hob themselves into the platen so that the platen is no longer parallel. When an appropriate mold for the machine platen is mounted, there is actually space between the mold and the platen in the center of the machine which under pressure of injecting the material will flex and allow the mold to flash. Molders

Getting the Bugs Out of New Molds

- Ideally, a machine should be set aside for testing new molds
- Dry cycle the mold
- Test the mold using a material that you have run successfully
- Build up temperatures and pressure gradually; record operational data such as material heats, pressure, cycle, and other pertinent data
- Open molds slowly when first shots are made, to check for defects in knockout system or on cavities or cores
- Mark with Prussian blue (machinist's transfer ink) or crayon any trouble spots, such as sticking, excessive flash, dragging and sciving, or other trouble

should occasionally check the parallelness of their platens to eliminate trouble. When there is not sufficient clamp on the machine, relieve the mold surface area.

Side Action Molds

Side action molds are generally actuated by means of angle pins. The angle pin, however, has a definite limitation as to the length of draw. Then hydraulic or pneumatic means, or the use of cams must be considered. The actuation of the mold is not all that must be considered in this type of design. Preventative measures must be incorporated to prevent the slide or core from pulling back under pressure of the material being injected into the cavities. This is generally accomplished by the use of wedges but the size and amount of lock of the wedge is important.

Unscrewing Molds

This is a complicated mold and requires technical knowledge to design it properly. The methods used to actuate the unscrewing are numerous: Rack and pinion, hydraulic motor, electrical motor, chain drive, groove core operating on the movement of the mold from the closed to open position, and undoubtedly others. The number of turns usually dictates whether mechanical or another action such as electrical is required. It is not always necessary to unscrew by means of spinning the core, sometimes it is advantageous to spin the cavity.

Knockout Methods

Knockout pins are the easiest and simplest to include in a mold and to maintain. But many times blade knockouts are desirable and the stripper plate more positive. Knockout pins or blades are, with few exceptions, cheaper to incorporate in a mold than a stripper plate, but a stripper plate is more positive. If knockout pins can't do the job, then a stripper plate is a necessity. In referring to a stripper plate it is generally considered as the intermediate plate between the cavity and the core retainer plate. Sometimes it is possible to just bore or cut into the stripper plate without using individual rings or stripper plate inserts. This is not suggested for long wear and long production or for critical parts.

Materials for Building Molds

The product often dictates that case hardening steel is required, as the cavities lend themselves to hobbing. But proper selection of the type of hobbing steel to assure the proper depth of case hardness is mandatory. Machine steels are used in some instances such as 1020 and then the molder wonders why there are pits, seams, or imperfections on the cavity or core. Good qualities of steel such as 420 stainless, when hardened, give less distortion and warpage.

The use of beryllium copper, while it offers in many instances a means of making a mold cheaper should not be overlooked for its advantage in cooling and therefore faster cycling, even if the cost of the material in that particular application results in a higher price for the mold. Like steel, there are different types of beryllium copper alloys; like steel, different hardnesses are obtainable. However, this material when hardened properly is highly resilient.

Beryllium copper, however, does not withstand abrasive action; therefore should not be used in compression molds. Beryllium copper should have much more support on the side walls of the cavities than is required of steel cavities. Another point: Beryllium copper can be repaired more readily than any steel. It can be welded using a heliarc welding unit so that the actual weld is not distinguishable by the naked eye and extreme build-ups are possible in cavities and cores by means of welding which would be considered nearly impossible in steel.

In conclusion, it is suggested that diligent preparation of one's own particular mold requirements be made, use the services offered in the form of technical assistance from the material suppliers, and realize that the best mold is the cheapest mold in the long run.

—— ■ ——

Plans Finalized for 18th Annual Technical Conference

PLASTICS REVOLUTIONIZE DESIGN is the theme for the 18th Annual Technical Conference of the Society of Plastics Engineers, to be held at the Penn-Sheraton Hotel in Pittsburgh, January 30 through February 2, 1962.

According to John E. Parks, general chairman of the Conference, "basic design techniques are being modified today because of new plastics. New plastic formulations, now being produced to ever higher tolerances and complexities, can provide the designer with, in effect, new products."

Highpoint of the conference is a technical paper to be presented by Professor Guilio Natta of Montecatini, Milano, Italy. His subject will be "Progress in Stereo-Regulated Polymers." Approximately 100 additional papers will be read.

Technical areas to be covered in the more than 26 sessions include new plastic formulations such as polyolefins, urethanes and polystyrenes (processing, properties and applications) reinforced plastics (uses and new developments in testing) and plastics-metals combinations. Other topics for discussion under plastics process technology are injection molding and extrusion; fast-moving blow molding and thermoforming, and auxiliary plastics processing equipment. In addition, special sessions are scheduled for applications of plastics in building and in space vehicles and missiles.

Planners of the 18th ANTEC include (front row from left to right) Robert R. Hornickel, ANTEC Secretary; John E. Parks, General Chairman; R. Bruce Johnson, ANTEC Treasurer; (rear row) Chester F. Stuver, Vice-Chairman, Arrangements; Ben A. Moreland, Finance Committee; and Lewis A. Bernhard, SPE Executive Office staff

BURNING STREAKING
CRAZING GAS MARKS
EXCESSIVE DOWNTIME
TOO LITTLE CAPACITY
TOO MUCH CAPACITY
HIGH SCRAP RATES
STRESS CRACKING
SILVER STREAKS
DIRT OR SPECKS
BRITTLENESS
EXFOLIATION
CORROSION

•

OBSOLETED
PRESS RATINGS

•

SPLIT OR
CRACKED CYLINDERS

Call us today.....we are as near as your phone!

IMS

FREE CONSULTATION ON YOUR HEATING CYLINDER PROBLEMS!

For more than ten years IMS has been the injection industry's clearing house on heating cylinder complaints of all kinds. Next time you have a press down for heater trouble or when you run into molding problems with the heat chamber, call IMS for an analysis of your specific difficulties.

It's our business to review your heating cylinder headaches. Because we have an industry-wide viewpoint on this one phase of injection molding, we believe you will find our comments constructive. If it appears that an IMS Replacement Heating Cylinder will solve your problem..... we are then prepared to design and build **TOP QUALITY LONG-LIFE HEATERS** to overcome whatever difficulty you reported to us. Our Service covers **ALL** makes and models of injection machines. In fact, IMS Heater Redesign Service can often save you the cost of a new machine by overcoming costly obsolescence factors in older presses.

We are **NOT** affiliated in any way with any of the original equipment makers. Therefore, as independent heating cylinder consultants, we offer you an unbiased appraisal of your special molding problems.

DON'T BUY YOUR OLD HEADACHES ALL OVER AGAIN!

Take advantage of our unique specialization to keep **ALL** your injection machines running at top efficiency with bigger heaters.....smaller heaters.....quick-clean heaters..... vinyl heaters.....etc. Wherever heater-caused loss factors are found, consult IMS for replacement chambers re-engineered to cut your molding costs! Prompt Delivery!

IMS

"...the **HEATING CYLINDER** people"

INJECTION MOLDERS SUPPLY CO., INC.
17601 SOUTH MILES ROAD • CLEVELAND 28, OHIO • LUdlow 1-3200

Hot sun causes some vinyls to give off volatiles that "fog" windows. Bar-O-Sil stabilizer inhibits this condition.

Tests show Bar-O-Sil* stabilizer inhibits troublesome "fogging" of car windows due to vinyls

Bar-O-Sil supplementary stabilizer also checks spewing, crocking, plating and blocking in processing of vinyl film, sheeting and extrusions.

Car manufacturers noted that heat causes some vinyl upholsteries to give off volatiles that "fog" windows. Tests show that Bar-O-Sil, complex barium silicate supplementary stabilizer, inhibits this condition in vinyls. In addition to alleviating this problem, Bar-O-Sil promotes the following desired characteristics in vinyl film, sheeting and extrusions.

Promotes colorant performance and "dry hand" qualities

Bar-O-Sil has a high adsorptive capacity that provides improved control of migration of color and plastic ingredients to the surface. Bar-O-Sil also has low reactivity with sensitive colorants. These important properties contribute to more effective control of bleeding, spewing and crocking during processing—promote desired color and "dry hand" qualities in vinyl film, sheeting and extrusions.

Speeds production runs by reducing plate-out

In all stabilizing systems containing barium, cadmium or zinc compounds, Bar-O-Sil reduces plate-out on rollers during calendering. In this way, Bar-O-Sil saves time by permitting quick color changeovers, and speeds production runs.

Other helpful benefits

Bar-O-Sil's high adsorptive capacity controls blocking of vinyls in storage and in use. The presence of Bar-O-Sil is important, especially when post-laminating or post-embossing operations are to be conducted as a separate step, some time after the initial processing stage.

Send coupon for more information

For detailed information covering the many useful properties imparted to vinyls by Bar-O-Sil supplementary stabilizer, fill out the coupon below.

**Trademark of National Lead Company*

KC-9899-D

NATIONAL LEAD COMPANY
General Offices: 111 Broadway, New York 6, N.Y.
In Canada: CANADIAN TITANIUM PIGMENTS LIMITED
1401 McGill College Avenue, Montreal, Que.

Gentlemen: Please send technical data sheet on Bar-O-Sil Stabilizer.

Name_____ Title_____

Firm_____

Street_____

City & Zone_____ State_____

BAR-O-SIL* *(Stabilizer)*

A Chemical Development of **National Lead Company**
111 Broadway, New York 6, N. Y.

Samuel L. Madorsky

National Bureau of Standards

POLYMER SCIENCE

Thermal Degradation of Organic Polymers

The jet and missile age has created an increased interest in the usage of polymers at temperature ranges of 600-1200°C. This article discusses thermal degradation of polymers from 200-1200°C and investigates some of the mechanisms involved. Such studies will aid the plastic engineer in material selection

When subjected to heat, organic polymers undergo various changes. Some of these changes, such as softening or melting, are of a physical nature, while others, particularly at more elevated temperatures, are of a chemical nature. A considerable amount of research has been carried out, mainly during the last 15 years or so, on the problem of thermal degradation of polymers, in most cases at temperatures up to about 500-600°C. However, during the past several years, with the advent of the jet and missile age, there has been a growing interest in the use of polymers at temperatures far above 600°C and research in this field has been extended to temperatures up to 1200°C.

It is the object of this paper to discuss the subject of thermal degradation of organic polymers in the temperature range between about 200° and 1200°C, limiting the discussion to the chemical changes that take place in the polymers during pyrolysis and to the qualitative and quantitative nature of the resulting volatile and non-volatile products. In order to simplify the discussion further in this paper, it will be limited to pyrolysis in a vacuum, or in some cases in a neutral atmosphere, since the reactions of oxygen with the products of degradation would mask the reactions that are caused by purely thermal effects. Since most of the data in the literature pertain to pyrolysis in a vacuum, this type of pyrolysis will be implied here unless stated otherwise.

Residues From Degradation

All organic polymers degrade and vaporize when subjected to sufficiently high temperatures. It has been found, however, that when they undergo a limited amount of thermal treatment, a decrease in the molecular weight takes place, indicating that scissions occur in the chain, even before any loss of weight is detected. As pyrolysis proceeds, vaporization of small fragments begins to take place, and the molecular weight drops still further.

Poly(methyl methacrylate), when heated at temperatures up to about 400°-500°C, breaks up almost entirely into monomer. Grassie and Melville (1) heated samples of benzoyl peroxide-catalyzed poly(methyl methacrylate) of molecular weights 179,000, 94,000, and 36,000 at temperatures up to 220°C. They found that after a 5-6% loss of weight the molecular weights of the two higher molecular weight samples dropped rapidly to 112,000 and 67,000, respectively, while the lower molecular weight one remained unchanged, until at least 65% degradation. These results, according to Grassie and Melville, indicate that in the initial stages of degradation of these polymers, during which the molecular weight stays constant, the reaction is such that splitting of the chains results in the formation of free radicals which proceed to decompose completely to monomer leaving no involatile residue.

Jellinek (2) heated polystyrene of an average molecular weight of 114,000 and measured the molecular weight of the residue in terms of limiting viscosities. He observed that in the initial stage of degradation a rapid drop in the viscosity takes place, which he ascribes to the presence of weak links in the chains. After a short time most of these weak links become ruptured, and then a straight-line relationship is obtained between loss of weight and the drop in intrinsic viscosity.

Madorsky (3) heated thermally-prepared polystyrene samples, molecular weight about 230,000, for 0.5-

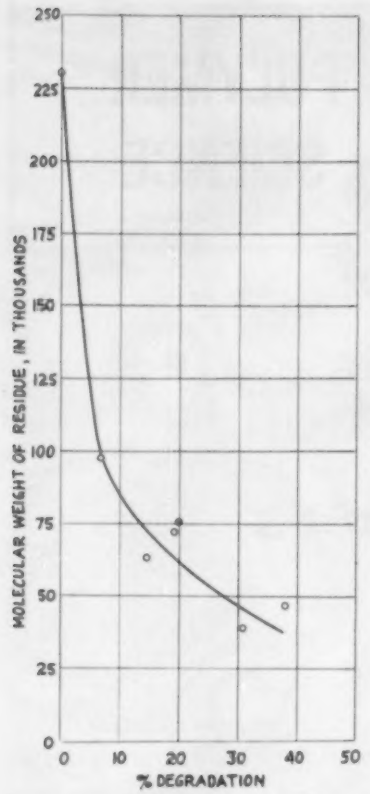


Figure 1. Molecular weight of polystyrene, residue versus % degradation after pyrolysis at 360-381°C for 0.5 hour

hour periods at temperatures varying from 360° to 381°C. The molecular weights of the initial material and of the residues, as determined by the osmotic-pressure method, are shown in *Figure 1* as a function of percentage degradation of the polymer. This same type of rapid drop of molecular weight during the initial stage of degradation was also demonstrated by Wall, Brown, and Hart (4) for two samples of poly(α-deuterostyrene), one of poly(β-deuterostyrene), and two of polystyrene. The results are shown in *Figure 2*.

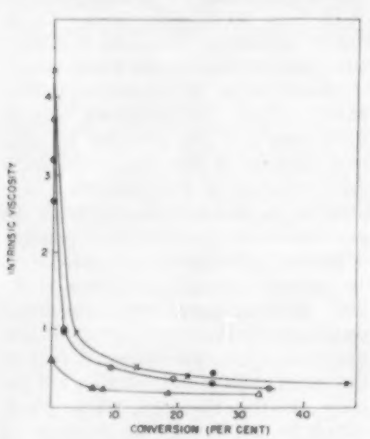


Figure 2. Intrinsic viscosity of polystyrenes after pyrolysis at 340°C: (X) α-deuterostyrene polymer $[\eta]_o = 4.37$, (x) α-deuterostyrene polymer $[\eta]_o = 3.18$, (O) styrene polymer $[\eta]_o = 3.71$, (half darkened circle) styrene polymer $[\eta]_o = 2.73$, (Δ) β-deuterostyrene polymer $[\eta]_o = 0.61$

As can be seen from *Figures 1 and 2*, most of the drop in molecular weight takes place before 5-7% of the sample is vaporized. However, further decrease in molecular weight does not show a straight-line relationship to loss of weight of the sample, as postulated by Jellinek. Instead, it shows a tendency to level off, as was also found by Grassie and Melville (1) for poly(methyl methacrylate). It seems that the initial drop in weight of the polymers discussed here may be due to some extent to weak links, as postulated by Jellinek, and it has been shown that long chains are less stable than short ones. When a long chain acquires thermal energy, this energy can appear mainly in the form of vibrational energy of its parts, and strains are produced causing ruptures in the chain. This will continue until a steady state is reached in which the frequency of ruptures in the chains is balanced by the disappearance of some of the shorter chains.

Most organic polymers vaporize almost completely when heated at temperatures below about 600°C. However, in the case of polymers which are highly crosslinked to start with, or those which develop excessive crosslinkages during pyrolysis, such as polytrivinylbenzene, poly(vinylidene fluoride), and polyacrylonitrile, a certain amount of residue remains, even when the pyrolysis temperature is raised far above 600°C. In *Figure 3*

Table 1. Distribution of Fractions in the Pyrolysis of Polymethylene in a Vacuum and in Helium

Expt. No.	Pyrolysis Temperature	Amt. of volatilization	Fractions, based on total volatiles: solid	liquid	gaseous
	°C	%	%	%	%
1[a]	500	99.4	94.1	5.9	Trace
2[a]	800	99.5	77.8	22.0	0.2
3[a]	1200	98.2	41.3	47.7	11.0
4[b]	500	99.2	82.9[c]	17.1	
5[b]	800	97.9	56.1[c]	43.9	
6[b]	1200	95.3	61.6[c]	38.4	

[a] Pyrolysis performed in a vacuum.
[b] Pyrolysis performed in helium at atmospheric pressure.
[c] Includes the gaseous fraction, which would be quite high at 1200°, judging from Expt. 3 in vacuum pyrolysis.

Table 2. Composition of Volatiles from Pyrolysis of Polymethylene in a Vacuum[a]

Component	Expt. 1 500°C	Expt. 2 800°C	Expt. 3 1200°C
	%	%	%
H_2	—	0.1	0.2
CH_4	—	0.1	3.6
C_2H_2	—	—	3.3
C_2H_4	—	5.5	26.4
C_2H_6	0.1	0.3	0.9
C_3H_4	0.1	0.2	2.7
C_3H_6	0.1	2.9	8.0
C_3H_8	0.2	—	0.5
C_4H_6	0.3	0.9	7.1
C_4H_8	0.3	3.9	3.1
C_5 to C_8 incl.	4.8	8.3	2.9
Waxlike fraction	94.1	77.8	41.3
Total	100.0	100.0	100.0

[a] In weight percent of total volatiles.

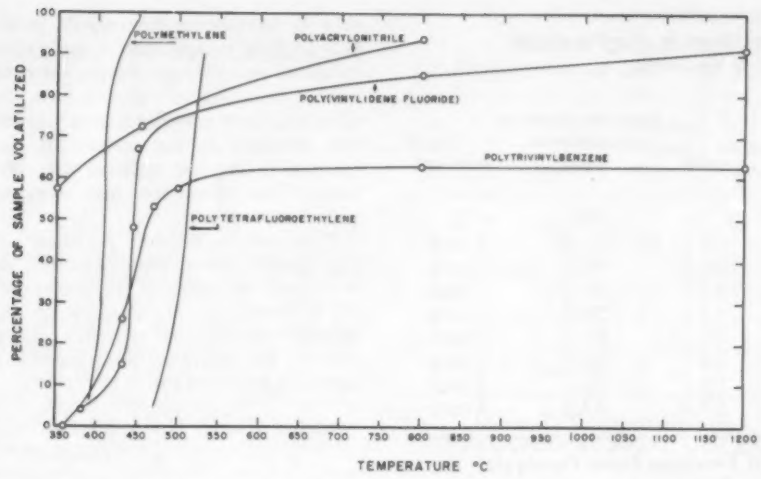


Figure 3. Relative thermal stability of high-temperature polymers as percentage of sample volatilized

(5), loss of weight due to vaporization is plotted as a function of temperature for these high-temperature polymers. Curves for polymethylene and polytetrafluoroethylene are shown here for comparison. The circles represent experiments where the heating period was 30 minutes, preceded by 15 minutes of preheating, for temperatures through 500°C, and 5 minutes, preceded by 2 minutes of preheating, for temperatures above 500°C. Analysis of residues (5) from polytrivinylbenzene pyrolyzed at 500°, 800°, and 1200°C, show the presence of smaller quantities of hydrogen as the pyrolysis temperature is raised, becoming only about 0.1% at the highest temperature. Similarly, the residues from poly(vinylidene fluoride) decrease in the percentage of both hydrogen and fluorine under the more drastic pyrolytic conditions.

Volatile Products from Degradation

In the earlier work on thermal degradation of polymers, the amount of sample used in pyrolysis experiments was very large as compared with that used in present-day research. Staudinger and Steinhofer (6) pyrolyzed a 208-g sample of polystyrene in glass retorts in a vacuum at 400-500°C and obtained a complex mixture of hydrocarbons. These products were fractionated, and on analysis they were found to consist of monomer, dimer, trimer, and some tetramer. In more recent work, sample sizes of the order of 1 to 50 mg were used in the study of the degradation process. The disadvantage of using a large sample lies in the fact that the slow rate of diffusion of the gaseous products from the sample will allow the products more time to be subjected to secondary reactions than when a smaller sample is used. Even if the material should be finely subdivided before experiment it would, in most cases, become a fused mass upon heating. When small samples are used, analysis of the degradation products by chemical methods becomes very difficult, particularly when these products consist, as in most cases, of a complicated mixture of compounds. Analysis is then most conveniently carried out, particularly for the smaller fragments, in a mass spectrometer. In order to facilitate such analysis, the volatilized products are usually fractionated into a solid fraction, one or two liquid fractions, and a gaseous fraction.

The solid fraction is wax-like, and ordinarily has an average molecular weight of 300-900, depending on the nature of the polymer and the temperature of pyrolysis (7-12). A microcryoscopic method can conveniently be used to determine the average molecular weight. Analyses of some of these solid fractions have shown them to consist chiefly of fragments of the polymer chain, but somewhat modified.

The liquid fractions obtained at pyrolysis temperatures below 500-600°C consist mainly of monomers, or of monomer-size fragments, of an average molecular weight of about 150. The gaseous fractions consist in most cases of small amounts of H_2, C_2H_2, C_2H_4, CH_4, and CO. For pyrolysis temperatures above 600°C the average molecular weight of all the fragments decreases with increase of temperature.

Composition of Degradation Products

The qualitative and quantitative composition of products of degradation as a function of temperature and pressure during pyrolysis is illustrated by the experimental data in *Tables 1, 2 and 3* (5). The distribution of fractions from pyrolysis of the nonbranched polymethylene in a vacuum and in helium at 500°, 800°, and 1200°C is shown in *Table 1*. In the

Table 3. Composition of Liquid Fraction from Pyrolysis of Polymethylene in a Vacuum and in Helium[a]

Component	At 500°		At 800°		At 1200°	
	Expt. 1, vacuum	Expt. 4, helium	Expt. 2, vacuum	Expt. 5, helium	Expt. 3, vacuum	Expt. 6, helium
	%	%	%	%	%	%
CH_4	—	—	—	0.2	3.1	0.1
C_2H_2	—	—	—	0.4	2.9	0.6
C_2H_4	—	2.1	5.4	11.9	22.3	16.2
C_2H_6	0.1	0.8	0.3	2.2	0.8	1.5
C_3H_4	0.1	0.1	0.2	0.2	2.1	—
C_3H_6	0.1	2.2	2.8	5.8	6.4	3.9
C_3H_8	0.2	0.8	—	0.6	0.4	—
C_4H_2	—	0.3	—	0.3	—	0.3
C_4H_6	0.3	0.5	0.9	1.7	5.4	1.3
C_4H_8	0.2	1.5	3.9	3.6	2.4	0.7
C_4H_{10}	0.1	0.3	0.4	0.3	—	—
C_5 to C_8 incl.	4.8	8.5	8.1	16.7	1.9	13.8
Total	5.9	17.1	22.0	43.9	47.7	38.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a] In weight percent of total volatiles.

Table 4. Distributions of Fractions in the Pyrolysis of Polystyrene in a Vacuum

Expt. No.	Pyrolysis temperature	Heating duration	Amt. of volatilization	Fractions, based on volatilization		
				solid	liquid	gaseous
	°C	hrs	%	%	%	%
1	336	1.0	22.1	58.0	42.0	Trace
2	336	2.0	40.6	58.6	41.4	Trace
3	339	3.0	78.5	61.0	39.0	Trace
4	339	4.0	91.4	63.2	36.8	Trace
5	354	0.5	47.2	50.2	49.8	Trace
6	373	0.5	91.1	54.0	46.0	Trace
7	375	0.5	88.5	56.7	43.3	Trace
8	375	0.5	94.7	57.4	42.6	Trace

Table 5. Composition of Liquid Fraction from Pyrolysis of Polystyrene in a Vacuum[a]

Component	At 336° Expt. 1, 1 hour	At 336° Expt. 2, 2 hours	At 339° Expt. 3, 3 hours	At 339° Expt. 4, 4 hours	At 354° Expt. 5, 0.5 hour	At 373° Expt. 6, 0.5 hour	At 375° Expt. 7, 0.5 hour	At 375° Expt. 8, 0.5 hour
	%	%	%	%	%	%	%	%
Styrene	39.0	39.3	37.6	34.8	47.8	44.2	41.0	40.7
Toluene	3.0	2.1	1.4	2.0	2.0	1.8	2.0	1.9
Total	42.0	41.4	39.0	36.8	49.8	46.0	43.3	42.6

[a] In weight percent of total volatiles.
Experiment numbers are the same as in Table 4.

case of pyrolysis in helium the gaseous fraction could not be separated from the helium at the liquid nitrogen temperature, and the yield of this fraction was therefore calculated together with that of wax-like fraction by subtracting the weights of the liquid fraction and the residue from the weight of the sample. In *Table 2* are shown the results of analysis of the combined gaseous and liquid fractions from pyrolysis in a vacuum. *Table 3* gives the results of analysis of the liquid fractions from pyrolysis both in vacuum and in helium. As can be seen from these three tables, a higher temperature and a higher pressure cause greater fragmentation of the degradation products.

In the case of polystyrene, distribution of fractions in vacuum pyrolysis at temperatures below 400°C is shown in *Table 4* (8, 13) as a function of temperature and duration of pyrolysis. The gaseous fraction appears only in trace amounts. Composition of the liquid fraction is illustrated in *Table 5* (8, 13). At higher temperatures and pressures polystyrene yields larger amounts of the smaller fragments (liquid and gaseous fractions) at the expense of the larger fragments (solid fraction). This is illustrated in *Table 6* (12). Duration of experiments at 850°C was only 35 seconds, as it was found that volatilization was complete in this time. Composition of the liquid fraction is illustrated in *Table 7* (12).

Greater fragmentation of the volatile products caused by the increase of temperature and pressure of pyrolysis is also encountered in the case of the solid fraction. The average molecular weight of the solid fractions from polymethylene pyrolyzed in a vacuum at 500°, 800°, and 1200°C, are 690, 562, and 473, respectively (5).

The greater fragmentation of the volatile products for polymers pyrolyzed at high temperatures may take place in the primary reactions, in which the rapid heating of the polymer to a high temperature causes a greater dissociation of the chain into smaller fragments than at lower temperatures. It may also take place in the secondary reactions in which the primary products may break up further while passing through the hot zone of the heating chamber, and the higher the temperature the greater the effect. The effect of pressure consists in hampering the volatile products in their escape due to molecular collision, and thus subjecting them to further break-up in the hot zone. In addition, there may be a catalytic effect involved in the contact of the gases with the hot walls of the container. This effect, too, may increase with temperature.

Pyrolysis of organic polymers at high temperatures, high pressures, or both, may be similar to thermal cracking of petroleum. For example, in the thermal cracking of paraffins above 700°C, the following reactions have been suggested (14):

$$C_nH_{2n+2} \rightarrow C_nH_{2n} + H_2 \quad (1)$$

$$C_nH_{2n+2} \rightarrow C_{n-1}H_{2n-2} + CH_4 \quad (2)$$

$$C_nH_{2n+2} \rightarrow C_{n-2}H_{2n-4} + C_2H_6, \text{ etc.} \quad (3)$$

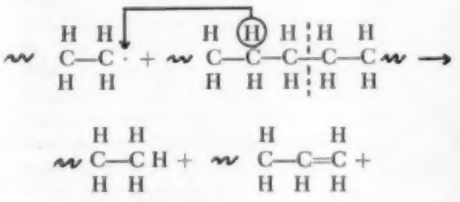
In catalytic cracking of hydrocarbons at temperatures above 300°C, the following compounds appear among the products (15):

$$H_2,\ CH_4,\ C_2H_6,\ C_3H_6,\ C_4H_8,\ \text{etc.}$$

Mechanism of Degradation

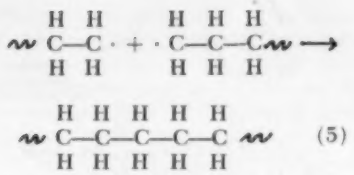
The mechanism by which a polymer breaks down into smaller fragments depends primarily on the molecular structure of the polymer. The breakdown of simple vinyl polymers takes place in accordance with various mechanisms, which are listed below:

1. Breakdown of the chain into a molecular spectrum having from one to about 50 carbons. The best example of such a polymer is polymethylene (5, 7). Simha, Wall, and Blatz (16) assume that after an initiation step of degradation has taken place, resulting in the formation of some free radicals, the main process of degradation depends on a transfer of the free-radical activity through hydrogen abstraction (Equation 4). Scissions take place at the dotted lines.



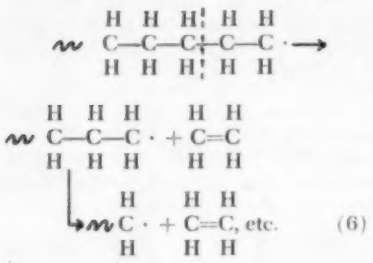
(4)

The newly formed free radicals could then go through similar reactions or become disproportionated by reacting with other free radicals according to Equation 5.



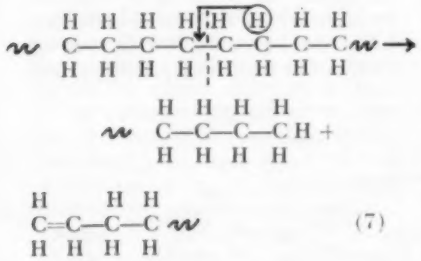
(5)

Experimental results of pyrolysis of polymethylene in a vacuum (5, 7, 11) at temperatures below 500°C indicate that the amount of ethylene in the volatile degradation products is negligible. However, if the process involves the existence of free radicals, then one would expect the formation of an appreciable amount of ethylene by an unzipping process illustrated in Equation 6.



(6)

Since the yield of ethylene is very small (7), it is assumed that the mechanism of thermal degradation of polymethylene takes place preferably by a transfer of H at the site of a bond scission. Due to the thermal energy acquired by the polymer chain, some bonds acquire enough energy to be ruptured, and the reaction can be visualized as shown in Equation 7.



(7)

2. Breakdown by a mechanism which results in the formation of monomers along with longer chain fragments of a molecular weight of up to about 900. It can be seen from Equation 4 that the above described mechanism 1. is determined by the abundance of hydrogen atoms on the polymethylene chain. If, however, some of the hydrogens are replaced with some other atoms or radicals, the displacement of hydrogen by intramolecular abstraction at the site of scission becomes limited, and the extent of this limitation increases with the decrease of hydrogen atoms on the backbone. As a consequence, some scissions result in the formation of free radicals, which can unzip into monomers (Equation 6), can react intermolecularly or intramolecularly (refer to Equation 4) or can disproportionate (Equation 5). In the case of vinyl polymers, the monomer appears in the degradation products in appreciable amounts. Thus, in polypropylene (7) and polyisobutylene (11) the monomer yields are 0.2% and 20%, respectively. These values are shown in *Table 8*, in which the monomer yields are given for a num-

Table 6. Distribution of Fractions in the Pyrolysis of Polystyrene at 362° and 850°C, in a Vacuum and in Helium

Expt. No.	Pressure	Pyrolysis temperature	Heating Duration	Amt. of volatilization	Fractions based on total volatiles solid	liquid	gaseous
	mm	°C		%	%	%	%
1	10^{-5}	362	1 hr	83	57	43	Trace
2	760 He	362	1 hr	83	45	55	Trace
3	10^{-5}	850	35 sec	100	32[a]	68	
4	760 He	850	35 sec	98	28[a]	72	

[a] Includes the gaseous fraction.

Table 7. Composition of Liquid Fraction from Pyrolysis of Polystyrene at 362°C and 850°C in a Vacuum and in Helium[a]

Component	Expt. 1 362°C, vac.	Expt. 2 362°C, He	Expt. 3 850°C, vac.	Expt. 4 850°C, He
	%	%	%	%
Ethylene	0	0	0	17.7
Ethane	0	0	0	1.6
Propadiene	0	0	0.5	0.6
Benzene	0	20.5	37.1	18.4
Toluene	2.1	3.1	3.8	16.6
Styrene	40.9	31.4	26.6	17.1
Total	43.0	55.0	68.0	72.0

[a] In weight percent of total volatiles. For conditions of experiments see Table 6.

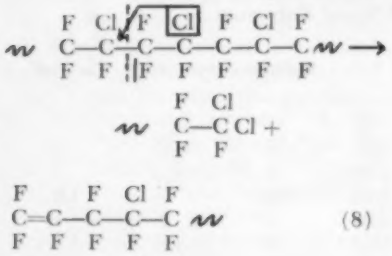
Table 8. Half-Life (T_h) and Monomer Yield in the Pyrolysis of Some Polymers

	T_h	Reference	Monomer[a]	Reference
	°C		%	
Polytetrafluoroethylene(Teflon)	509	5	>95	18
Polymethylene	414	5	Trace	7
Polytrifluoroethylene	412	18	0	18
Polybutadiene	407	9	2	11
Branched polyethylene	404	9	Trace	11
Polypropylene	387	9	0.2	7
Polychlorotrifluoroethylene(Kel-F)	380	9	27	9
Poly-β-deuterostyrene	372	9	39	7
Polystyrene	364	5	40	16
Poly-α-deuterostyrene	362	8	68	8
Poly-m-methylstyrene	358	8	45	8
Polyisobutylene	348	5	20	11
Poly(methyl acrylate)	328	8	Trace	8
Poly(methyl methacrylate)	327	5	91	8
Poly-α-methylstyrene	286	5	>95	8

[a] In weight percent of total volatilized part.

ber of polymers pyrolyzed in a vacuum at temperatures below 600°C. Polystyrene (13), which is really a polymethylene in which one of the hydrogen atoms on alternate chain carbon atoms is replaced by a phenyl group, yields on pyrolysis below 500°C 40% monomer (*Table 8*).

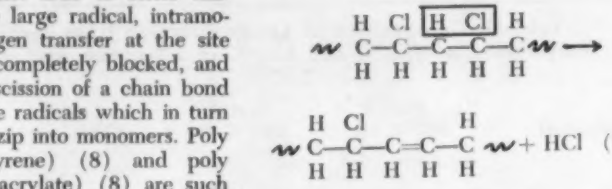
3. Breakdown by a mechanism yielding almost 100% monomer. This is the case, for example, with polymers in which one of the hydrogens on alternate carbons is substituted by a methyl radical and the other hydrogen by a larger radical such as a phenyl or ester. Due to steric hindrance of the large radical, intramolecular hydrogen transfer at the site of scission is completely blocked, and as a result a scission of a chain bond forms two free radicals which in turn proceed to unzip into monomers. Poly (α-methyl styrene) (8) and poly (methyl methacrylate) (8) are such polymers. When heated at temperatures up to about 500°C, the monomer yield is almost 100% (*Table 8*). To this group of polymers belongs also polytetrafluoroethylene (Teflon), although steric hindrance is not involved here. In this polymer fluorine atoms replaced all the hydrogen atoms on the polymethylene chain. The C-F bond is much stronger than the C-H bond (17); as a result, when this polymer is heated at temperatures up to about 600°C (18) a chain scission forms two free radicals, which proceed to unzip into monomers (*Table 8*). However, in polychlorotrifluoroethylene (Kel-F), where one chlorine atom replaces a fluorine atom on alternate carbons in Teflon (9), some transfer of the chlorine takes place in an intramolecular abstraction, such as in Equation 8.



(8)

As a consequence the monomer yield at pyrolysis temperatures below about 500°C is only 27% (9). This can be explained on the ground that the C-Cl bond is weaker than the C-F bond (17).

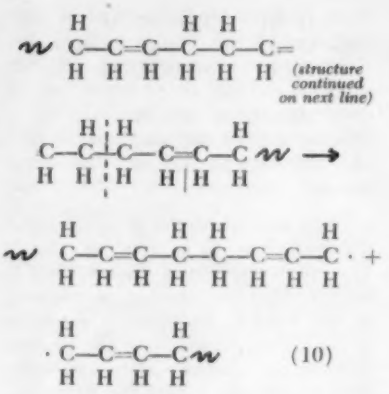
4. Breakdown into large chain fragments and small molecules, where most of the latter are not related to the structural unit of the polymer. An example of such polymers is poly (methyl acrylate) (8). When pyrolyzed at temperatures below 500°C, it yields mainly CO_2 and CH_3OH and very little monomer (*Table 8*). Other examples are poly(vinyl chloride) (19), poly(vinyl fluoride) (18), poly (vinylidene fluoride) (18) and polyacrylonitrile (10). The chloride, the fluoride, and the nitrile polymers decompose to yield, in addition to fragments of various sizes, HCl, HF, and HCN, respectively. Thus, in the case of polyvinyl chloride, for example, the mechanism of acid formation is as follows; (Equation 9):



(9)

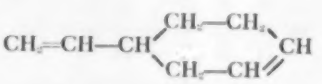
This represents a simplified overall reaction. A detailed discussion of this reaction was given by Stromberg, Straus, and Achhammer (19). When the double bonds accumulate in the backbone of this type of polymer, carbonization takes place (*see Figure 3*).

Considerably less is known about the mechanism of degradation of the diene polymers. In polybutadiene (11), the bulk of the volatile products consists of long-chain fragments. The smaller fragments of molecular weight of up to 100-110 consist primarily of butadiene, butene, and vinyl cyclohexene (dimer). The C-C bonds in the butadiene chain, which are in β-position to a double bond, have the weakest links in the chain and are more likely to rupture than the other bonds. Formation of the monomer is assumed to take place according to Equation 10:

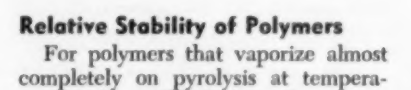


(10)

and each of these free radicals may react further by an unzipping process to give monomers or dimers; to abstract hydrogen atoms from the surrounding medium; or to disproportionate. The dimer cyclizes into vinyl cyclehexene



Similarly, in the case of polyisoprene, the small fragments in the degradation products consist primarily of the monomer and the dimer (dipentene) (11).



Relative Stability of Polymers

For polymers that vaporize almost completely on pyrolysis at temperatures below 600°C the relative stability can be established by heating them under equivalent conditions and

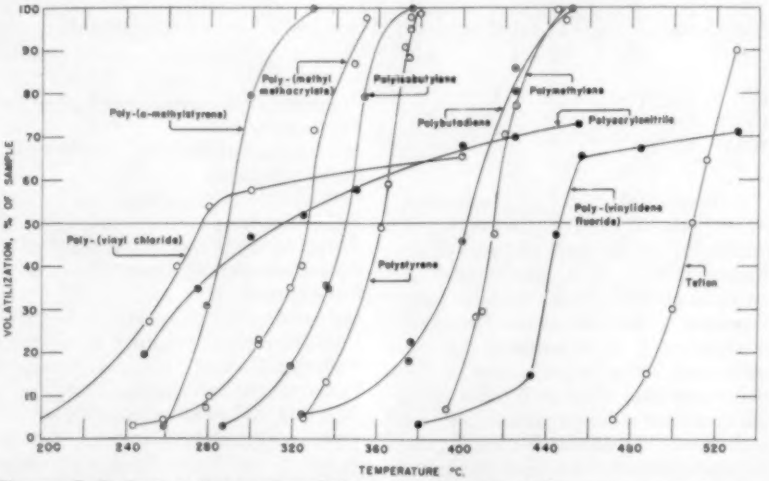


Figure 4. Relative thermal stability of polymers at lower temperatures

comparing the amount of vaporization sustained. This is illustrated in *Figure 4* for several polymers (12), each circle representing an experiment of vacuum pyrolysis for 30 minutes. Loss by vaporization is plotted in this figure, as a function of temperature. The curves thus shown, except those for poly(vinyl chloride), polyacrylonitrile, and poly(vinylidene fluoride), seem to have generally the same shape, and the relative thermal stability of the polymers represented by these curves is obvious. However, another convenient method of representing relative thermal stability (9) is to compare characteristic temperatures of the polymers, designated as T_h, which is the temperature in degrees Celsius at which a polymer vaporizes 50% of its weight and thus represents the temperature of "half-life" of the polymer under the standard conditions of pyrolysis indicated above. A series of polymers arranged in the order of their decreasing stability, based on T_h values, is shown in *Table 8*. However, polymers such as poly(vinyl chloride), polyacrylonitrile, and poly(vinylidene fluoride), which develop crosslinking during pyrolysis, or polytrivinylbenzene, which is highly crosslinked initially, do not vaporize completely, even at temperatures far above 500°C (see *Figure 3*). The T_h scale can therefore not be used to measure the relative thermal stability of these polymers. A more appropriate scale of comparison in these cases would be the amount of carbonaceous residue remaining after pyrolysis and the extent of carbonization of the residue (5).

Conclusions

Studies of pyrolysis of simple organic polymers can serve a very useful purpose for the polymer scientist or for the plastic engineer. It leads to an understanding of the mechanisms involved in the reactions of thermal degradation and of the relationships between thermal stability, products of degradation, and molecular structure. Of particular interest to the plastic engineer is the fact that such studies should aid him in the selection of specific polymers to meet specific requirements and should make it possible to tailor polymers to meet specific requirements.

Literature References

1. Grassie, N. and Melville, H. W., *Faraday Soc. Discussions*, p. 378 (1947).
2. Jellinek, H. H., *J. Polymer Sci., IV*, 13 (1949).
3. Madorsky, S. L., *J. Polymer Sci., IX*, 133 (1952).
4. Wall, L. A., Brown, D. W., and Hart, V. E., *J. Polymer Sci., XV*, 157 (1955).
5. Madorsky, S. L., and Straus, S., *J. Chem. Ind.*, London, 1961, in press.
6. Staudinger, H., and Steinhofer, A., Ann. 517 (1935).
7. Madorsky, S. L., and Straus, S., *J. Research Natl. Bur. Standards 53*, 361 (1954).
8. Straus, S., and Madorsky, S. L., *J. Research Natl. Bur. Standards 50*, 165 (1953).
9. Madorsky, S. L., and Straus, S., *J. Research Natl. Bur. Standards 55*, 223 (1955).
10. Straus, S., and Madorsky, S. L., *J. Research Natl. Bur. Standards 61*, 77 (1958).
11. Madorsky, S. L., Straus, S., Thompson, D., and Williamson, L., *J. Research Natl. Bur. Standards 42*, 499 (1949).
12. Madorsky, S. L., and Straus, S., *J. Research Natl. Bur. Standards 63A*, 261 (1959).
13. Madorsky, S. L., and Straus, S., *J. Research Natl. Bur. Standards 40*, 417 (1948).
14. Sachanen, A. H., "Conversion of Petroleum. Production of Motor Fuels by Thermal and Catalytic Processes", pp. 4, 5 Reinhold Publishing Corp., 1940.
15. Emmett, P. H., "Catalysis", Vol. VI, p. 410, Reinhold Publishing Corp., 1958.
16. Simha, R., Wall, L. A., and Blatz, P. J., *J. Polymer Sci. V*, 615, (1950).
17. Cottrell, T. L., "The Strengths of Chemical Bonds", 2nd Edition Butterworth's Scientific Publications, 1958.
18. Madorsky, S. L., Hart, V. E., Straus, S., and Sedlak, V. A., *J. Research Natl. Bur. Standards 51*, 327 (1953).
19. Stromberg, R., Straus, S., and Achhammer, B. G., *J. Polymer Sci. XXXV*, 355 (1959).

This article is based on a paper presented before the SPE Baltimore-Washington Section in February 1961.

Edited by
Dr. Irvin Wolock
U.S. Naval Research Laboratory

SPE Sponsors New Book— ENGINEERING DESIGN for PLASTICS

All author appointments have been made for the third Plastics Engineering Series volume to be published under the auspices of SPE's Technical Volumes Committee. Authors will be announced at a later date, according to Dr. Eric Baer, Editor of the book, and Dr. Raymond F. Boyer, Chairman of the Technical Volumes Committee.

Dr. Baer, Professor of Chemical Engineering at The University of Illinois, reports that the purpose of the new book is to provide an individual interested in applying plastics with a **fundamental** text which may be used to solve practical problems. The book should be of use to industry as well as government and educational institutions. The book should be of most value to the applied scientist or engineer who needs a comprehensive text on the solid state properties of plastics and on the generc design methods for these materials. Ultimate goal of the book is to place designing with plastics on a sound scientific basis.

The first volume in this Plastics Engineering Series published by the Society was Quality Control for Plastics Engineers, edited by Lawrence M. Debing, and the second was Processing of Thermoplastic Materials, edited by Dr. Ernest C. Bernhardt, The Du Pont Co.

Clearer Rigids?

Where the problem is to create clearer rigids—with excellent stability and at low cost—the answer is Mark 99.

This new Argus stabilizer supplies superior heat and light stability. It also eliminates the problems of cross-staining and offensive odor that occur when more costly tin mercaptide systems are used.

Is your present objective clearer rigids? Low temperature flexibility? Non-toxicity? Good air release and bubble break in plastisols? More economical stabilization of electrical compounds?

Whatever your vinyl problem—*check with Argus.* If we don't have your answer in our present Mark stabilizers and Drapex plasticizers, we'll research it for you in our lab.

Argus Has the Answer

Technical bulletins and samples on request

ARGUS CHEMICAL Corporation 633 Court Street, Brooklyn 31, N.Y. Branch: Frederick Building, Cleveland 15, Ohio

Rep's.: H. M. Royal, Inc., 11911 Woodruff Ave., Downey, Cal.; Philipp Bros. Chemicals, Inc., 10 High St., Boston; H. L. Blachford, Ltd., 977 Aqueduct St., Montreal. European Affiliates: SA Argus Chemical NV; 33, Rue d'Anderlecht, Drogenbos, Belgium—Lankro Chemicals, Ltd.; Salters Lane, Eccles, Manchester, England.

SPE JOURNAL

Vol. 17, No. 7, July, 1961

The presence of a compatible additive may introduce difficulties during manufacture or degradation during the service life of the polymer. Suitable alkyl substitutes which are an integral part of the molecule induce steric hinderance, and consequently introduce superior plasticizing properties to the system

Cured Phenolic Resins Plasticized by Substituents on the Aromatic Ring

James H. Freeman *and* **Edward J. Traynor**
Westinghouse Research Laboratories

Cured polymers frequently are partially softened by means of an added compatible low molecular weight ingredient which serves as a plasticizer. This results in a greater resiliency of products made from such materials, at least for the early period of the products' life. Sometimes the presence of the plasticizer molecules may introduce difficulties during the manufacture of articles containing the material, or during its subsequent service life. Frequently, these difficulties are traceable to the migratory nature of the plasticizer compounds. It becomes desirable then to prepare polymers which possess the attributes of plasticized systems, but in which these properties result from some feature of the molecular structure of the polymer and not from additives.

Printed and Etched Circuit Features

Printed or etched circuits for wiring of electronic and electrical devices require a relatively cheap, laminated core stock which can be bonded to the copper foil surface. It must be a suitable electrical insulator and be capable of withstanding the necessary subsequent manufacturing operations such as acid etching, soldering, and stamping or punching, without either blistering or delaminating, and without any sticking, cracking or crumbling in the die press. Phenolic resins impregnated into sheet cellulose fillers are normally used for such applications. In general, they are too brittle unless the material is either highly plasticized or else is preheated prior to the punching operation.

For economic reasons, it is desirable that the laminate punch cleanly at room temperature. Added plasticizers are not completely satisfactory since they may result in blistering of the laminate in the soldering operation or separation of the conducting foil surface if the product is subsequently operated at an elevated temperature. With long time aging in service below the blistering temperature, the material may still shrink or become degraded and embrittled due to migration and eventual escape of the plasticizer molecules. The desired properties must be achieved in a thermoset material in order that the piece may maintain its structural integrity on heating in service. Thus, a self plasticized polymer in which the plasticizing action results from an integral part of the molecular structure, hence will neither volatilize on heating nor migrate away during service, was sought.

Plasticizer Mode of Action

When a stress is applied to a plastic material, it is thought that it first tends to uncoil the polymeric chains and then break primary valence bonds when rupture of the piece occurs. Both processes require energy. The cohesive forces holding the polymer rigid are assumed to consist of two types. Primary valence bonds make up the principal structure and serve to maintain the shape on heating. Secondary forces between polar centers in the molecule act as additional crosslinks under ordinary conditions.

The mode of action of most plasticizer molecules is assumed to be the interspersing of their own molecular entities between the high polymer molecules, thus diluting the otherwise normally strong attractive forces between

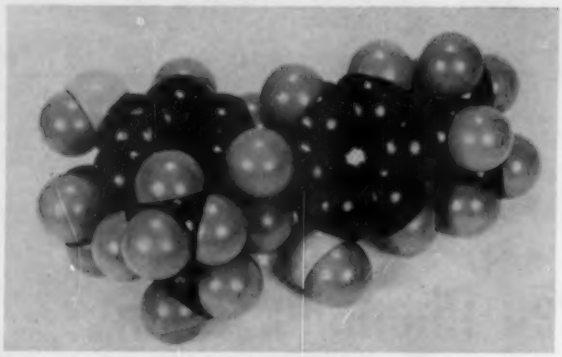


Figure 1. Model of dihydroxydiphenylmethane showing how isopropyl substituents are forced into position perpendicular to plane of benzene ring when adjacent to methylene bridge groups.

these molecules. Many phenolic resins as well as others can readily be punched hot. The effect of heat is to provide energy necessary to overcome the secondary bond forces and permit polymer segments to relocate.

Our object was to reduce the energy necessary to punch a laminate successfully without appreciably reducing the ultimate strength of the material, and to obtain this effect as a function of the structure of the molecule itself, rather than by means of external additives.

In phenolic resins, the principal secondary forces take the form of hydrogen bonds. The action of heat and/or plasticizers is to destroy hydrogen bonds in a given system. As an alternative, it was reasoned that, since for secondary bonds in general, and hydrogen bonds in particular, the bond strength is an inverse function of distance between polar centers, an improvement might be realized by preventing the close approach of such centers in and between polymeric chains. The phenol molecule is planar. A substituent which is out of plane to the greatest extent should create the maximum interference to the close approach of the planes and thus, of the polar hydroxyl groups attached to these planes. The problem then becomes one of introducing steric hindrance.

Substitution Materials for Plasticizing Phenolic Resins

Steric hindrance is a function of size of the attached group. For alkyl groups, the greatest hindrance is caused by chain branching. Extended length of the chain beyond the second carbon atom is not effective because the chain is free to conform to any configuration and will extend itself beyond the area where steric hindrance is a factor. It became desirable then, to prepare a resin from a phenol having a substituent which was branched at the carbon atom attached to the phenyl ring. Suitable examples considered were tertiary butylphenol, isopropylphenol, cyclohexylphenol, "octyl" (di-ter. butyl) phenol and phenylphenol.

Since it was also desired to interfere as little as possible with the normal primary valence bond structure of the resin, a meta substituted phenol was indicated. The ortho and para positions then remain free for reaction with formaldehyde. Use of some ortho or para substituted phenol as a coreactant was not excluded, however. Use of a dimeta substituted phenol was deemed undesirable because of the known depressant effect of such compounds upon the curing ability of the resulting polymer (1, 2) (i.e. such phenols are really only pseudo trifunctional toward formaldehyde).

Among the suitable meta substituted phenols, the most readily available in quantity was isopropylphenol.* Examination of an atom model of a polymer based on this reagent indicated that the adjacent methylene bridges in the resin chain would serve to keep the meta isopropyl group oriented perpendicular to the plane of the aromatic ring. (*Figure 1.*) Presence of such groups also serves to restrict the freedom of the rings to rotate about the methylene bridge. This compound therefore became the principle subject of our investigation. The findings seem to confirm the hypothesis as described and have made possible for the first time a cold punching grade laminate to which no extraneous substances were added.

Experimental

Pure m- and p-isopropylphenols were provided by Hercules Powder Company. The o-isopropylphenol was a product of the Koppers Company. 3-m-Pentadecylphenol was supplied by Irvington Varnish and Insulator Company. Other phenols were obtained from Eastman Kodak Company.

Resin Preparation—Phenols or modified phenols were added to a reaction vessel along with formaldehyde as 37% Formalin solution. The catalyst (4 mole percent of ethylenediamine based on total phenols present) was then added and the mixture heated under reflux with constant stirring for one hour at about 100°C. Vacuum was then applied to the emulsified resole. As the water removed approached the theoretical amount from a linear condensation, the resin became darker and a sharp temperature rise followed. The maximum temperature of each resin varied depending on the modified phenols originally employed. (*Table 1*). Each reaction was stopped when it gave indication that further dehydration would lead to gelling

Table 1. Resins from m-Isopropylphenol

No.	Mole Ratio of Phenolic Components*	150°C Gel Time (min.)	Maximum Kettle Temp., °C
1	1:1 meta-isopropylphenol:phenol	7	92
2	2:1 meta-isopropylphenol:phenol	12	94
8	5:1 meta-isopropylphenol:phenol	~30	96
3	All meta-isopropylphenol	66	126
10	1:1 meta-isopropylphenol: para-isopropylphenol	82	135
6	2:1 meta-isopropylphenol: para-isopropylphenol	41	132
9	2:1 meta-isopropylphenol: para-isopropylphenol	88	126
14	4:1 meta-isopropylphenol: para-isopropylphenol	41	142
13	2:1 meta-isopropylphenol: para-isopropylphenol*	64	140
11	2:1 meta-isopropylphenol: para-cresol	56	148
12	2:1 meta-isopropylphenol: para-hydroxdiphenyl	52	150
15	2:1 meta-isopropylphenol: ortho-isopropylphenol	120	126
20	3:1 meta-isopropylphenol: 3-n-pentadecylphenol	>60	126

* All resins have F/P ratio 1.5 except No. 13 where ratio was 1.2.

* Subsequent to this investigation, m-tertiary butylphenol became available to us. An attempt to prepare a resin based on this material led to great difficulty in curing the polymer. From atom models, it would appear that the t-butyl group is so large that it interferes with the formation of the necessary methylene bridges on the adjoining positions. Although we did no further work in this direction, it would seem that the compound might have merit if used in conjunction with a trifunctional compound such as m-isopropylphenol to restore the crosslinking ability.

within the kettle. After reaching the temperature indicated, the resin was diluted with alcohol and poured into a suitable container. The formaldehyde to phenol mole ratio was F/P = 1.5 in all cases except resin number 13 in which a ratio of 1.2 was used.

Laminating Procedure—Before impregnating the paper, the resin viscosity was adjusted to the optimum using alcohol as diluent and comparing with standard Gardner tubes. A viscosity reading of A to C was used for all except resins 1 and 2 where a reading of D was obtained. The solids content of the resin solutions were in the range of 40-50% at these viscosities. Cotton linter papers were dipped in resin and the excess allowed to drain. Impregnated paper was then dried in an air circulating oven at 150 ± 2°C except in the case of resins number 1 and 2 where 120°C was used because of the very short gel time of these products.

"Greenness" (weight percent of resin to flow out of a nine ply test laminate in five minutes at 155°C and a pressure of 1000 p.s.i.) was measured and the proportion of resin to filler prior to laminating was determined by dividing the weight of paper impregnated with resin by the original weight of the paper. A ratio between 2.1 and 2.7 was maintained with 2.2 to 2.5 being the preferred limits. Drying time in the oven was controlled to keep the greenness within the range of 5 to 20% (9 to 15% preferred). In general, a higher greenness value should be used with a higher ratio impregnated paper. The final laminate was made by pressing the required number of treated sheets at 1000 p.s.i. for 20 to 40 minutes at 155°C and cooling under pressure.

Punching Test—The various laminates were punched at room temperature (25°C) using a test die and evaluation in accordance with ASTM D617-44 (4). This machine simultaneously punches a test piece and various diameter holes in the piece. The punched sample is then evaluated with regard to cleanness of the hole and edge cuts and freedom from cracking or blooming (delamination) of the

Table 2. Punching Properties of Laminates from Isopropylphenol Resins

Resin No.	Laminate Thickness* (mils)	Punchability Rating** (Average)	Comment
1	75	11	Chipped, cracked
	75	17	& broken with
	62	30	drag on die.
	60	40	
	50	43	
2	56	77	Holes & edges OK
	55	60	but cracks &
	52	65	blooming of
			surfaces.
8	60	71	Holes & edges
	55	75	good. Surface
	53	77	subject to
	49	78	blooming.
3	54	11	Rating varied
	54	50	with extent of
	54	90	curing.
10	63	81	Holes & edges
	61	83	good. Surface
			cracks &
			blooming.
6	62	90	Excellent in
	55	95	all respects.
	53	97	
	53	92	
	52	98	
	51	97	
	51	96	
	47	98	
	47	95	
9	71	86	Thicker samples
	71	86	excellent on
	63	87	brief warming.
	58	95	
	57	88	
	57	85	
	53	95	
	53	97	
14	62	90	Slight blooming
	60	85	near holes. Other-
	47	95	wise excellent.
13	70	66	Tendency to crack
	70	71	at holes. Punches
	47	90	well warm.
			(F/P = 1.2)
11	72	81	Excellent on
	62	88	warming.
	56	86	
	51	83	
12	73	73	Excellent on
	62	71	warming.
	43	90	
	43	91	
15	61	77	Blooming &
	56	75	some drag at
	46	91	holes.
20	72	86	Good material
	62	95	generally.
	53	95	
18	68	90	Tower treated
	68	91	materials.
	62	93	
	60	85	
	59	91	
	58	91	
	54	95	
	54	95	
	52	95	
19	64	85	Tower treated
	56	85	materials.
	54	90	
	54	90	
	52	90	
	50	91	
	47	93	
16	64	88	Tower treated
	63	81	materials.
	54	95	
	52	90	
	50	90	
	50	93	
	35	91	

* Each value represents a separate board.
** Ratings are average of assigned values for holes, surface and edges according to Ref. 4.

Table 3. Electrical Properties of Some Isopropylphenol Laminates

Resin No.	Punch Rating	Dissipation Factor 100 x tan δ				Dielectric Constant			
		60 cy	1 Kc	500 Kc	0.8 Mc	60 cy	1 Kc	500 Kc	0.8 Mc
1	30	3.1	2.0	4.0		5.4	5.2	4.7	
2	65	2.3	1.7	3.1		5.2	5.1	4.6	
3	90	2.2	1.5	2.5		4.4	4.3	4.0	
6	90	6.6	3.0	3.0		5.0	4.7	4.2	
	92	4.7	2.3	2.7		4.7	4.4	4.1	
	98	4.3	2.3	2.1		5.0	4.8	4.4	
	97	5.6	2.8	3.0		4.9	4.6	4.1	
9	88	4.7	2.3	2.6		4.7	4.4	4.1	
18	90				3.5				4.0
	91				3.0				4.0
	91				4.0				4.1
	95				3.1				4.0
20	86				2.9				3.6
	95				2.7				3.7

surface. A number from zero to 100 is assigned to the edges, surface, and holes respectively, rating them against pictorial standards in the ASTM publication. Final rating of the punching is the average of the three values, a perfect sample being rated 100. Because of many variables in processing of both resin and laminate, differences of less than 5 units in punch rating between samples are probably not significant.

Punch ratings tended to become poorer with increasing thickness. The products described were intended for use in 1/16 inch (62.5 mil) thick copper surfaced laminates. All data reported in this paper were taken on samples before application of the copper foil surface. With our best formulations, it was still difficult to obtain consistent ratings above 90 on thicknesses greater than 56-58 mils. In general however, presence of the copper surface would be expected to improve the punch rating somewhat, and the thickness attained falls within tolerance limits for XXXPC grade material as specified in NEMA LPI 10.02.

Solder float tests and vapor degreasing tests were made to establish the cured nature of the products. A sample cut from a laminate showed only slight bleaching with no delamination or other deterioration when subjected to the vapor of boiling trichloroethylene for a period of one hour, followed by four hours drying at 110-120°C. (NEMA, LP1-10.09 requires only two minutes exposure.) Another sample was not visibly affected by floating in molten solder for 60 seconds at 246°C. (NEMA, LP1-10.08 requirement: 10 sec.)

Postforming Test—A wooden forming mold was used similar to that described in the NEMA Standard (5). Three samples of laminate, 1/16 x 2 x 6 inches, were cut from a board and placed in an air circulating oven for 90 seconds at 260°C. Each was quickly transferred to the mold which was immediately closed and a pressure of 250 p.s.i. applied. The mold causes a bend of 90° in the center of the piece across the two inch dimension and additional bends of 45° in the opposite direction across the same dimension near each end of the piece. Inside radii of the 90° bends are 3/32 inch and outside radii measure 5/32 inch.

A laminate for the test was prepared from resin number 6. Cotton duck cloth of the grade known as chafing duck was cut on a bias and dipped in resin solution having a viscosity of 0.80 poise. After draining, the cloth was placed in an air circulating oven for eight minutes at 145-150°C. The weight ratio of impregnated to unimpregnated cloth was found to be 2.5; greenness 20%. For a 1/16 inch laminate, five sheets were pressed on preheated platens at 155°C. A pressure of 500 p.s.i. was applied for 20 minutes and the laminate cooled under pressure. The product was light tan in color and well bonded. Before postforming, the board possessed a dielectric constant of 5.54 at 1 Kc and 4.71 at 500 Kc. The dissipation factor (tan δ) at the same frequencies was 0.055 and .045 respectively.

Comparison of Experimental Data

Comparative data from this investigation appear in *Tables 1 to 3*. Evidence of the cured nature of the final products was found in their resistance to solvent extraction and to the hot solder test. Some observations of interest follow.

With one exception, all of the resins studied contained meta isopropylphenol and formaldehyde at a mole ratio of 1.5 formaldehyde to total phenol. Various modifications were made by substituting other phenols for a portion of the meta isopropyl compound, (*Table 1*). Additional combinations are, of course, possible. Correlations with punching properties appear in *Table 2*.

Resins 1, 2 and 8 contained the indicated proportions of unmodified phenol. None of these resins exhibited desirable punching qualities regardless of fabricating techniques employed in the lamination of a board. In resin number 3, the meta isopropyl compound was the only phenolic constituent. Depending somewhat on processing techniques, cold punch ratings up to 90 were possible with this resin.

A group of resins (numbers 10, 6, 9 and 14) was then prepared containing mixtures of meta and para isopropylphenols. The presence of the p-isopropyl substituent serves to reduce the functionality of that portion of the phenol from 3 to 2 relative to the formaldehyde. It also enhances the possibility of the formation of some benzyl ether links instead of methylene bridges if the formaldehyde content is held constant (3). This factor did not seem to introduce any significant effect however, in view of the large number of other variables. (Resin 13 with a lower F/P ratio could be made punchable depending on thickness and greenness and resins 3, 10 and 14 failed to reveal any trend relative to resins 6 and 9.)

Although various proportions of meta to para isomer were tried, the 2:1 ratio appeared to be nearly the optimum with regard to final properties of the laminate. This also corresponded closely to an available commercial mixture of the isomers, favoring its use on economic grounds.

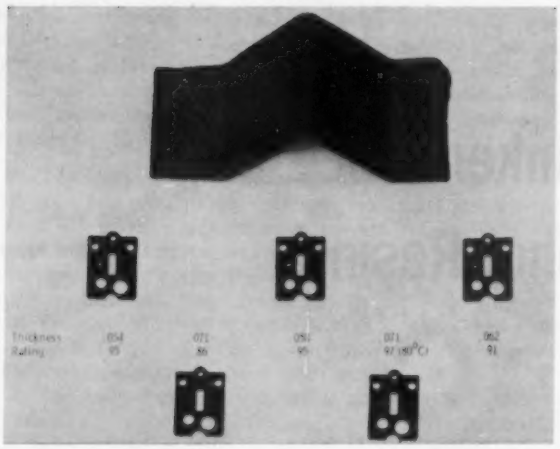


Figure 2. Punched and postformed laminates from isopropylphenol resin.

Since the chief purpose of the para substituent was to reduce the functionality of the phenol, it was thought that any alkyl or aryl radical might be substituted for this component in the formula. Using the 2:1 ratio of meta to para isolog, two additional resins were prepared in which the para substituent was a methyl group and a phenyl group (numbers 11 and 12 respectively). These products were not quite the equal of the all isopropyl system in overall properties but punched very well on warming.

In respect to this, it is noteworthy that virtually all of the laminates prepared from the meta isopropyl substituted phenol compositions of this investigation gave nearly perfect punchings (rating > 95) with only slight warming. As a rule, heating in an oven for only five minutes at 80°C was sufficient. This contrasts favorably with the recommendation of 15 minutes heating at 135°C specified by the ASTM standard (4) for hot punch materials. In these cases also, no difficulty was encountered in punching thicknesses up to at least 75 mils. It appears that a certain amount of success in reducing the energy requirement for punching was achieved in all the polymers based on isopropylphenol.

Resin 15 was prepared to test the assumption that the close proximity of the ortho isopropyl group to the adjoining hydroxyl group might further impair the hydrogen bond forming ability of this group. However, no additional benefit attributable to this component was found.

Resin 20 employs a long chain substituent (3-n-pentadecyl) in combination with the m-isopropylphenol. The punching results indicate that such compounds can be successfully incorporated as coreactants.

Some electrical properties of the laminates based on isopropylphenol resins are given in *Table* 3. It was also shown that a preimpregnation of the paper with a dilute solution of methylolphenol or early stage polymer before resin impregnation resulted in improved electrical properties of the laminate, particularly as to water immersion, without undue sacrifice of punching properties. Merely using diluted resin for the preimpregnation solution did not give a similar result. Resins 16, 18, and 19 are repeat preparations of resin 9 on a larger scale and were used for continuous tower treatment of large amounts of paper. preimpregnation treatment was used with these materials.

A further property of laminates which may be presumed related to the secondary valence bond structure of the polymer is the ability to be bent or drawn from a flat sheet into shapes after warming. Cracking and crazing must be avoided and the product must retain the new shape. This property of postforming is normally achieved by plasticization or by initial undercuring of a resin having a long cure period.

A cloth laminate based on m-, p-isopropylphenol resin number 6 was tested for this property according to NEMA Standard LP1-12.10. The post-formed samples were visually inspected at all bends with the aid of a 45 power microscope. No indication of crazing of the resin nor cracking of the cloth fibers could be observed. The angle retained by three samples after removal from the form was 91, 91.5 and 92 degrees respectively. The National Electrical Manufacturer's Association (NEMA) specification (5) calls for retention of an angle of not over 93°.

For comparison, a sample of a post forming grade laminate using similar reinforcement was obtained from a commercial manufacturer and tested in the identical fashion. The resultant piece was darkened in color, some incipient crazing was evident under the microscope, and the retained angle was 95°.

Effectiveness of this self plasticization was further demonstrated by the fact that our post formed boards could be returned to the oven for the prescribed ninety seconds and then repressed to their original flat condition. The process could subsequently be repeated with corresponding bends in the opposite direction with no apparent damage to the piece. Aging of the laminates at room temperature also had no effect on the post forming property. After a period of four and one half years on the shelf, a sample post formed as readily as it had originally.

Conclusions

In summary, it has been demonstrated that self plasticized, laminated materials suitable for punching and postforming applications can be produced from polymers based upon suitably substituted phenolic components, especially meta isopropylphenol, while avoiding the incorporation of any extraneous plasticizer compounds together with the difficulties attendant upon them (*Figure* 2.) Admittedly, the work reported herein does not unequivocally prove the hypothesis upon which it was based. The observed improvement in the properties of the product may conceivably be due to some factor which was not considered by the authors. On the other hand, the degree of success attained with a minimum of trial and error effort does constitute a strong endorsement of the inductive analytical approach to problems of this nature. A successful product was initially demonstrated within three months from the time the problem was first proposed and the complete program involved less than one man year effort.

Literature References

1. Martin, R. W., *Chemistry of Phenolic Resins*, p. 125, John Wiley and Sons, New York, N. Y. (1956).
2. Shepard, A. F., U.S. Pat. 2,732,368, January 24, 1956.
3. Rodia, J. S. and Freeman, J. H., *J. Org. Chem.*, *24*, 21 (1959).
4. ASTM Standards Part III, p. 390 (D617-44), 1944 Edition, American Society for Testing Materials, Philadelphia, Pa.
5. NEMA Standards Publication LP-1-12.10 (1959), National Electrical Manufacturer's Association, New York, N. Y.

This paper was presented as part of the Symposium on Plasticized Thermosetting Systems sponsored by the Division of Organic Coatings and Plastics Chemistry at the 138th Meeting of the American Chemical Society, New York City, September, 1960.

New Crosslinkers for Furfuryl Alcohol Resins

New crosslinking process produces furfuryl alcohol resins which are flexible, have excellent electrical characteristics and adhere to metals

Erik R. Nielsen

Armour Research Foundation of Illinois Institute of Technology

Commercial furfuryl alcohol resins are low-viscosity liquids produced by the treatment of furfuryl alcohol with a relatively strong acid at elevated temperature. Under these conditions, furfuryl alcohol undergoes intramolecular condensation to build up linear chains consisting of furan nuclei joined by methylene bridges.

Reactions Involved

"The chemistry involved is shown in *Figures 1, 2 and 3*. *Figure 1* shows the condensation of 2 mols. of furfuryl alcohol to form 5-furfurylfurfuryl alcohol which is capable of condensing with more furfuryl alcohol in similar manner, and so on, until a poly(furfuryl alcohol) chain is built up. Some of the double bonds of the furan nuclei in the poly(furfuryl alcohol) are broken by the action of heat and catalyst to produce sites for crosslinking with formaldehyde. The new crosslinkers to be described here are believed to act through the hydroxyls of the end groups. The condensation may take another course, by which difurfuryl ether is formed, as shown in *Figure 2*. Under the conditions, difurfuryl ether breaks down to give formaldehyde and difurylmethane. The latter polymerizes readily, presumably by way of ring opening, and the formaldehyde acts as a crosslinking agent. The extent of the ether formation is not known. A third reaction takes place also in which levulinic acid is formed, as shown in *Figure 3*. Thus, in case of liquid resins produced with an alumina catalyst, sufficient levulinic acid is formed to make the pH of the resin between 5 and 6. However, the resin is still stable at this pH."

In order to obtain a product, which is stable on storage, the acid catalyst is neutralized early in the reaction. Thus the commercial products contain large amounts of unreacted furfuryl alcohol. If the acid is not neutralized or if acid is added again later on, the linear chains are lengthened and crosslinking takes place. At the same time the resin goes through viscous and rubbery stages to the final thermoset stage, at which the resin is black, infusible, hard, and brittle.

Application Problems

The fully cured resin is resistant not only to alkali but also to most acids and solvents. Notwithstanding these

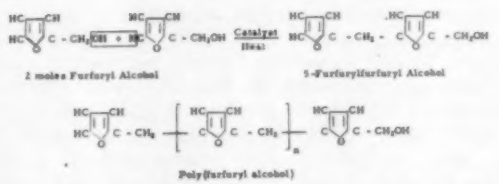


Figure 1. Condensation of two moles of furfuryl alcohol to form 5-furfuryl-furfuryl alcohol, which polymerizes by continued condensation with furfuryl alcohol.

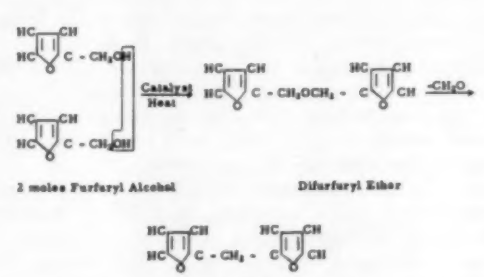


Figure 2. Furfuryl alcohol condensation to difurfuryl ether, which breaks down to give formaldehyde and difurylmethane.

Figure 3. Furfuryl alcohol reaction with water to give levulnic acid.

unusual properties for a relatively low-cost resin, commercial application of these resins has been slow. The one exception is their use in corrosion-resistant cements, for which application they have been found to be outstanding. There are a number of reasons for this limited acceptance of a resin with high chemical resistance:

1. The black color is a disadvantage in some cases.
2. The fact that relatively strong acid catalysts are required to effect complete cure essentially prohibits the use of cellulosic fillers and necessitates special corrosion-protective measures for the molds and platens in preparing laminates with these resins (1).
3. The acid catalyst remains as such in the cured resin and has a deleterious effect upon the electrical properties, which otherwise should have been excellent.
4. The fully cured resin is brittle and lacks adhesion to metals (2).
5. The actual polymer content of commercial liquid furfuryl alcohol resins is low because of the necessity of stopping the conversion at a point where it is still practical to neutralize the acid catalyst. To be sure, the monomeric furfuryl alcohol contained in such liqud resins will be condensed or resinified when an acid catalyst is added again for the thermosetting process, but the water of condensation produced thereby may give rise to troublesome porosity in the final product.

Crosslinking Methods

The problem of producing liquid furfuryl alcohol resins with a high polymer content was solved some years ago (3). However, since the resins had to be thermoset with an acid catalyst, the fully cured resins were brittle and lacked adhesion to metals, as in case of the conventional resins. This current paper presents a method for thermosetting a liquid furfuryl alcohol resin without the use of an acid catalyst, instead, a suitable crosslinker is employed.

It is generally agreed that crosslinking with formaldehyde (developed as a byproduct in the resinification process) plays an important part in the thermosetting of a furfuryl alcohol resin intermediate with an acid catalyst. In the absence of a strong acid formaldehyde crosslinks at a much slower rate, and the thermoset resin formed eventually is brittle and lacks adhesion to metals. It has now been found that a number of compounds are capable of crosslinking furfuryl alcohol resin intermediates quickly and efficiently without the aid of a strong acid. Examples of such crosslinkers are polyamides, polyfunctional amines, polyfunctional amides, amino acids polyfunctional in basic groups, and hydrazine (4).

The idea that a polyfunctional amine can be used to thermoset a furfuryl alcohol resin intermediate may be startling, since it is well known that basic compounds inhibit the resinification of furfuryl alcohol (5). In this connection, it should be remembered that the new crosslinkers are simply crosslinkers and not resinification catalysts. It follows from this that the use of the new crosslinkers is most effective with relatively highly converted liquid furfuryl alcohol resins, since any monomeric furfuryl alcohol present will remain as such and will be lost when the crosslinking process is accelerated by the application of heat. It also follows that monomeric crosslinkers should not be employed in substantial excess, but a polymeric crosslinker may be used in excess advantageously if it is compatible with the crosslinked resin.

About 2 or 3% of the new crosslinkers is sufficient, and larger amounts do not cause further crosslinking. Crosslinking probably occurs at the terminal hydroxyl groups, the number of which is limited. This may explain why the crosslinked resins are more flexible than the conventional thermoset resins but more sensitive to aromatic and ketone solvents. The conventional thermoset furfuryl alcohol resins are undoubtedly crosslinked at several points along the chains, and this accounts for their brittleness and insensitivity to aromatic and ketone solvents.

Test Procedures

An example of the new crosslinking process is as follows. A liquid furfuryl alcohol resin was mixed with General Mills' Versamid 125 in the ratio of 100:25, and steel panels were coated with the mixture. The coated panels were baked at 150°C for 10 min.

Test data have been obtained for a furfuryl alcohol resin prepared with activated alumina denoted as A resin, of approximately 275 cps and for two commercial furfuryl alcohol resins (B and C, of approximately 150 cps). All three resins gave coatings which could be bent over a ⅛-in. mandrel and showed impact strengths of about 2 ft-lb. For all three resins the insulation resistance (measured by applying 500 volts d.c. between the front and the back of the panel) was about 3×10^{10} ohms, the dielectric constant was about 5.2, and the power factor was about 0.007.

Test panels were also immersed halfway in various liquids for 48 hr at room temperature. All the coatings were unaffected by 25% sodium hydroxide. With 33% sulfuric acid, all the coatings were stripped from the panels. The coating itself was intact in the case of resin A but was wrinkled in the case of the resins B and C. The coating of the A resin was not affected by 5% nitric acid, the coating of the B resin was blistered, and the coating of the C resin was etched. Water immersion had no effect upon resin A, but in case of resins B and C the coatings were stripped from the panels and were etched. The coatings all swelled in toluene, benzene, and acetone, but did not dissolve. All the coatings were unaffected by chlorinated solvents and aliphatic hydrocarbons.

Tests run with a 15,000-cps resin, prepared with activated alumina, gave results comparable to those obtained for the 275-cps resin.

The crosslinking process described has been applied successfully to coatings, and it has been established that the crosslinked resins adhere well to steel and copper. Attempts to apply the process to casting or molding of substantial thicknesses of material have been unsuccessful. The resin fails to cure properly under such conditions; this phenomenon is being investigated.

Conclusions

In summary, the new crosslinking process can provide furfuryl alcohol resins which are flexible, adhere to metals, and have excellent electrical characteristics, whereas conventional furfuryl alcohol resins are brittle, do not adhere to metals, and have poor electrical characteristics. The new resins can be used with cellulosic materials, whereas the conventional resins cannot. The acid and alkali resistance of the new resins is comparable to that of the conventional furfuryl alcohol resins, but the new furfuryl alcohol resins swell in active solvents.

Literature References

1. Dunlop, A. P. and Peters, F. N. The Furans. ACS Monograph No. 119, 784, 1953.
2. Reineck, E. A. *Modern Plastics*, Oct. 1952.
3. Nielsen, Erik R. *SPE J.* 9, 10, 1953; U.S. Patent No. 2,681,896, June 22, 1954.
4. Patent applied for.
5. Dunlop, A. P. and Peters, F. N. *Ind. Eng. Chem.* 34, 814, 1942.

Hydraulics on Plastic Injection Molding Machines

Interested in surveying hydraulic systems? Functional, maintenance and design aspects are discussed here

R. H. Mezger
Vickers Incorporated Division Sperry Rand Corporation

The primary function of hydraulics on injection molding machines is to transmit the power from the electric motor to the die cylinder and plunger cylinder. Although the basic function of hydraulics is the opening and closing of the die and the injection of the plastic, hydraulics is frequently used for auxiliary functions such as the operation of die spacing cylinders, nozzle adjusting cylinders, transfer cylinders, core pulling cylinders, and for provision of a safety interlock.

Hydraulic System Advantages

There are four basic ways to transfer power from one point to another—*mechanical, electrical, pneumatic* or *hydraulic*. Each method has its own advantages and limitations. The advantages of a hydraulic system are listed below:

Hydraulic power transmission is more flexible than mechanical and usually easier to install. It has a lower weight to power ratio than electrical and provides more precise control than pneumatic because air is more compressible than oil. Hydraulics provides a smooth, positive, compact, safe, easily controlled, and easily installed means of regulating force, speed, and direction of power.

Maintenance

Hydraulic systems need attention and service to assure trouble-free operation. Like any piece of precision machinery, a hydraulic system requires regular maintenance to avoid unexpected breakdowns and to prolong life. Preventive maintenance enables you to avoid many troubles, or to detect and correct them before they become serious. A hydraulic system usually gives a warning of trouble before a breakdown actually occurs. Frequent inspection of a few simple things will enable you to detect these warning signals before the trouble is serious.

Some of the warning signs to watch for are:
External leakage—noticeable at pumps, valves, and fittings.
Low fluid level in tank—permitting air to be drawn into pump.
Noisy operation—particularly in the pump but also in the valves and piping.
Slow operation—possibly caused by pump and valve wear.
Overheating of the fluid—resulting in loss of lubrication and pump wear, excessive leakage both internal and external, sludge formation and sticking valve parts.
Contaminated fluid—the greatest single cause of trouble in hydraulic systems. This contamination may consist of foreign material, sludge, water or air.

Preventive maintenance means any action taken to avoid possible future trouble with the operation of a machine. This can be an elaborate program including the keeping of complete records of each report of trouble, action taken, down time, costs, etc. . . It can also be a simple program consisting of the machine operator or maintenance personnel periodically checking the machine operation before trouble develops and reporting any warning signs of potential trouble. Each company or department should decide what degree of preventive maintenance best meets its requirements. The important thing is that every company should be aware of the need and importance of preventive maintenance, and develop some definite program.

The first requirement in a preventive maintenance program is to *teach* the maintenance personnel and machine operators to *recognize* trouble signs. It is important that the symptoms of the trouble be detected early.

There are many sources of help and information regarding the details of hydraulic maintenance. The machine manufacturer and hydraulic equipment manufacturer can supply you with advice and literature regarding the maintenance of the equipment. Some manufacturers offer training programs on basic hydraulics for customers.

Only trained and qualified men should be permitted to work on the hydraulic systems. High pressure hydraulic equipment is precision built with as little as .0002" clearance between moving parts. These relatively small hydraulic components control tremendous power. The servicing of this type equipment requires special training and "know how".

Design Improvements

Many improved hydraulic designs have been made available during the past few years. Some of the more spectacular improvements are manifested in lower cost high pressure pumps and in solenoid valves with greatly increased flow capacities and much longer solenoid life. The trend is to pack more power into less space. This means even higher pressures and increased valve capacities in the future. One of the limiting factors in attaining higher pressure is leakage. The trend to higher pressures will encourage the use of straight thread connections and gasket mounted valves on drilled or brazed manifolds. To maintain good efficiency at higher pressures, closer clearance will be required in the hydraulic units. This will place an even greater emphasis upon the need for improved filtration and temperature control of the fluid.

Although the hydraulic industry has already made great progress, continued research and development will provide us with many improved, new and revolutionary products in the future. This means to you greater power transmission capacity per dollar of component cost.

Adequate plastic standards are lacking for appliance component manufacturers, especially in safety considerations. This article investigates test methods, standardization and categorization of plastic materials for this end use

Plastics in Electrical Appliances

Louis M. Kline
Underwriters' Laboratories, Inc.

Since the end of World War II, more and more plastics have been encountered in the electrical appliances submitted for investigation and listing by Underwriters' Laboratories, Inc. This organization is chartered as a non-profit organization without capital stock, to establish, maintain, and operate laboratories for the examination and testing of devices, systems, and materials. Founded in 1894, the enterprise is sponsored by the National Board of Fire Underwriters, and is operated for service, not for profit, in the interest of public safety.

The wide use of plastics could not be anticipated, therefore, the Laboratories' published Electrical Appliance Standards include few specific requirements for plastics. We have in the meantime developed requirements for our appliance classifications and this information is available to all manufacturers.

As each new plastic or plastic application was encountered, the Laboratories was confronted with the basic problem of how to evaluate the plastic. As indicated above, it is the practice of Underwriters Laboratories to recognize or list a product or material only after the completion of an acceptable investigation including a study of available field record and technical data. Some plastics were judged as unsuitable for the proposed use during the discussion stages. Others fell by the wayside when the user could not support his proposed use with technical or test data and chose not to initiate an investigation to establish the facts.

From the beginning, we have taken our usual stand of not being influenced by factors not related to safety; such as, cost, styling, production problems, and the like. At the same time, we realized that as the plastic art advances, improved and better products will be made available to the Appliance Industries and that our door must be kept open for these advances.

Test Programs

In many instances, plastics of the slow-burning class in reasonable quantities have been accepted without test or investigation where the plastics are used for decorative parts; such as, trim, trays, and knobs.

When a plastic cannot be evaluated without an investigation, a test program must be created. It is our aim that the program be realistic, technically sound from an engineering standpoint, and one which can be executed within a reasonable length of time at a justifiable cost. Whether for plastic or any other new material, one method of establishing a test program is based on our long-standing new materials comparison approach. By this approach, the properties affecting safety of the new material are compared with the properties of the material being replaced. This method gives rise to both manufacturing and testing problems. First, we may be asked to compare two materials so completely different in nature that a suitable test program is difficult, if not impractical, to achieve. Secondly, we can carry out the test program only on the finished product. This typically means for plastics that the manufacturing molds must be fabricated before the investigation. Thirdly, a completely new device, having no counterpart of conventional materials, cannot be fitted into such a program. There are undoubtedly other problems related to this approach, but those already stated established the pattern of difficulties.

Undesirable time and economic loss is encountered when the test schedule of a plastic being investigated under the comparison program renders inconclusive or unacceptable results. This leads us to consider other investigation programs. This consideration also arises when a plastic has no counterpart for comparison.

Another approach to the evaluating of a plastic is to conduct a special investigation of a single type plastic for a specific application; using a test program so devised that the material and its application can be judged on its own merits. Such investigations are usually costly, time-consuming, and provide the answer for only one named material under a limited environment. This time-consuming element, the need for finished samples, and the financial burden placed on an individual manufacturer makes the program somewhat undesirable. In addition, individual investigations of different plastics for use in different electrical appliances have a tendency to create different requirements in the different classifications. Thus, a plastic may be acceptable in one electrical appliance, and at the same time, may not be considered acceptable in a second because the original investigation did not explore one or more of the plastic's characteristics needed for the second appliance.

As we are aware of most of the problems related to the direct acceptance, comparison, and merit programs, we continue to search for better or improved methods of evaluating and categorizing plastics.

Plastic Categorization

Individuals and groups have long recognized that for the good of the Plastics Industry and all Industries using plastics, it is necessary that the plastic selected be proper and suitable for each distinct application or use, that plastics be categorized to the degree which will permit the designer to select a suitable plastic early in the design stage

before the molds are fabricated, and that a method be devised to enable the designer to judge the electrical hazards of an electrical appliance when plastics are employed.

In line with the preceding desires, Underwriters' Laboratories, Inc. is conducting an extensive fact-finding investigation sponsored by the Manufacturing Chemists Association, Inc. The investigation in broad terms is to determine through survey, study, and tests where plastics can be used safely in electrical appliances. In more specific terms, the scope of the investigation is, (1) to survey the field record of plastics in respect to fire, shock and accident hazards, (2) to interview informed people, such as fire marshals, inspectors, appliance manufacturers, and service centers, (3) to categorize the basic characteristics of all established families of plastics considered suitable for use in electrical appliances, (4) to explore heat and ignition sources within typical electrical appliances; such as, window air conditioners, and to study their flame paths, (5) to create, if possible, methods of testing and/or judging plastics at the design level, and (6) to establish a source of technical information and data related to the safe application of plastics in electrical appliances.

The Underwriters' Laboratories research group works in cooperation with Manufacturing Chemists Association appointed Technical Advisory Committee. The eight committee members, who represent large and small electrical appliance manufacturers, plastic fabricators, and basic plastic resin manufacturers, meet with the research group from time to time as the investigation progresses. It is the purpose of the Technical Advisory Committee to review the work completed after each phase of the work and to review the proposed test program for the next work segment. In addition, they make available to UL a ready source of technical information and background material. Manufacturing problems not directly related to safety are not within the scope of the investigation.

Over 40 different molded or foamed plastic materials are included in the investigation. The performance characteristics being considered are flammability, ease of ignition, rate of burning, fuel contribution, arc tracking, heat distortion, flexural strength aging, water absorption, and impact.

One of the first steps considered pertinent to the fact-finding investigation is the grouping of the submitted materials according to the classifications used in the listings of basic plastic materials. In this list, plastics are classified with respect to their comparative fire hazards as slow-burning or self-extinguishing, depending on the performance of representative specimens of the materials in specified burning tests. The test methods are described in Underwriters' Laboratories' Bulletin, Subject 94, dated December 9, 1959. Where plastics are used in electrical appliances, the assignment classifications of the fire hazard of the basic materials may serve as a preliminary indication of their suitability for a particular appliance application.

As a second step in the investigation, the general characteristics of the plastics are being compared or grouped by using existing accepted test methods. In some instances, because of the extremes of the characteristics, the test methods are altered as deemed necessary. In our search for suitable test techniques, we have created new test methods or have integrated new and old methods into a more appropriate procedure.

For example, all samples are being subjected to our standard flame test, described in the previously mentioned UL bulletin. As these tests disclose that the burning rate cannot readily be determined on the low melting point materials, repeat tests are being conducted with each test sample supported by a wide mesh screen.

In order to explore the characteristic ease of ignition, bar samples of plastic are wrapped with five turns of No. 24 Stl. W.G. soft iron wire spaced ¼ in. between turns. The wire is then brought to a red heat by passing 8 amperes through it. The samples are held horizontally during testing. Observations are made of the smoke conditions and the time required to fire the sample. As we have found this test is severe for certain families of plastics, additional tests are being conducted with a single turn of wire and with other wire configurations. By this approach, we seek to devise a test method which will be simple and reproducible, and will categorize typical plastics with respect to ease of ignition. The other characteristics are similarly treated.

To associate electrical disturbances with plastics, relatively high capacity short circuit tests are being made adjacent to, and spaced from, samples of plastics. By this test, a plastic sample may be damaged, carbonized, melted, or fired when located in contact with a source of short circuit energy whereas additional tests may demonstrate that the sample plastic is uneffected when located away from the energy source by a nominal spacing.

In addition to the testing of specific plastics, the investigation includes the study of electrical devices and equipments with respect to their being a source of ignition or abnormal heating for the plastics used in them. The study includes the determination of flame paths throughout electrical appliances. This may show how a flame spreads to plastic parts that are not located near the ignition or heat source.

After performing fundamental characterization tests on specimens, each plastic family could then be placed into an engineering "pigeon-hole."

Conclusion

If an appliance designer had the project to design an over-all enclosure for use adjacent to a high-energy electrical source where arcing might occur, he would be able to refer to the data on materials already cataloged. He could then select a material which was suitable, (1) for enclosure use, (2) from a heat distortion standpoint at the temperatures anticipated, (3) from an arc-resistant standpoint at the voltages being enclosed, and (4) at the spacings necessary in the design. In the selection of a plastic by this proposed method or some similar method, the designer would be able to select his material before tooling with fair assurance that the material would be suitable in the end application. When the final product is ultimately submitted for investigation, the work would not include basic characteristic tests but would stress identification tests, the measurement of spacings to high temperature and/or high electrical energy parts, the temperatures and electrical energy encountered, the flame paths, and other routine tests called for by the Standard covering the product.

By the category method, a formulator of plastics could submit a new plastic suitable for electrical appliances for recognition. After conducting the basic tests, the new material would be cataloged and could be substituted for any other material having the same basic characteristics. Even if such a category method proves satisfactory for only certain groups of plastics, it should still prove a valuable tool.

In the preparation of a standard for an electrical appliance, the standard could specifically indicate what basic classification of plastics are required for the various applications within the appliance. This, in turn, would expedite the investigation of an electrical appliance using plastics.

Upon completion of work at the Underwriters' Laboratories a Fact-Finding Report will be prepared for the Manufacturing Chemists Association, who will, disseminate the information as they see fit.

Microdispersed Formaldehyde-Arene Resins

Emulsion resinification technique now used to prepare thermally stable microdispersed resins from the catalyzed reaction of an arene with formaldehyde. Raw materials are cheap and available in this system with the potential product applications in the areas of gelling and thickening agents.

J. E. Goodrich

California Research Corporation

The preparation of resins by the reaction of an aromatic compound (arene) with formaldehyde using an acid catalyst was first described by Nastyukov (9) in 1903. He labeled this the "formolite reaction, (10) and the products are often called formolite resins.

Two types of resins, along with volatile by-products, form in the arene-formaldehyde reaction. The resin that predominates at elevated reaction temperatures is soluble in most organic solvents, is thermoplastic, and has a softening point up to about 285°F. This type is essentially oxygen free. (4, 7) Numerous methods of preparation and uses have been patented (1, 2, 3, 5, 6, 8, 11, 12). The type of resin that predominates at ambient reaction temperatures is infusible, is insoluble in all common solvents, and contains significant amounts of oxygen. No commercial use has been made of these infusible resins.

This paper describes the preparation of microdispersed, infusible resins. These thermally stable resins with small particle size and large surface area thicken a variety of organic and aqueous systems. The simple preparation of these resins from inexpensive, readily available reagents provides a new type of material for industrial use.

Preparation

The resins are prepared by the slow addition of formaldehyde to a stirred mixture of sulfuric acid, carbon tetrachloride, and aromatic compound at room temperature. The resinous product separates immediately. To prepare a microdispersed product, it is necessary that (a) an efficiently stirred reaction vessel, such as a turbomixer, be used and (b) a dispersant be added to emulsify the sulfuric acid in the carbon tetrachloride. In a typical experiment, benzene (41.4 g., 0.53 mole), 96% sulfuric acid (345 g.), calcium petroleum sulfonate (1 g.), and carbon tetrachloride (960 ml.) were charged to a glass turbomixer at 70°F. The mixture was stirred vigorously, and 38% formaldehyde solution (60 g., 0.76 mole formaldehyde) was added dropwise during 40 minutes, keeping the reaction temperature below 90°F with a cold water bath. The thick reddish-black slurry was poured into cold methanol and filtered. The precipitate was washed with water, dilute ammonium hydroxide (the resin turned bright yellow on contact with base), and finally with acetone. The yield of dried resin was 43.5 g.

The preferred reaction temperature is 90°F. At this temperature, the smallest resin particles are formed. Sedimentation radii of the particles were calculated from settling rates of the smallest particles of 0.5% dispersions of resin in hexane and plotted in *Figure 1* as a function of reaction temperature. In this method, the size of resin agglomerates, but not the individual particles, is measured. The discrete resin particles are less than 0.1 micron in diameter; they

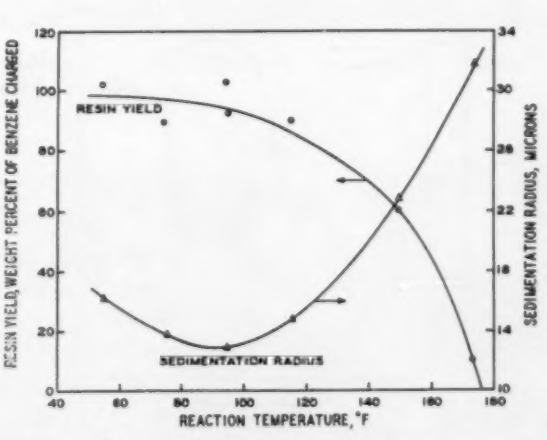


Figure 1. Effect of reaction temperatures on microdispersed benzene-formaldehyde resin yield and particle size. 90°F is the preferred reaction temperature.

form clusters in hexane with radii of 12 microns or more. Although the sedimentation radii are not direct measures of particle size, they do indicate relative thickening power The resins produced at 90°F had smaller sedimentation radii and were more efficient thickeners of mineral oil than those produced at higher or lower temperatures. *Figure 1* also shows that infusible resin yields decrease at reaction temperatures above 90°F. Solvent-soluble resin formation predominates above 160°F.

The reaction constituents are discussed below.

Aromatics—Numerous arenes formed infusible resins under the above conditions. These materials are listed in *Table 1*, along with the weight of resin produced. Both pure compounds and petroleum fractions are included. Most of our work employed benzene as the arene.

A number of aromatics did not form infusible resins but instead gave colored, solvent-soluble products. Examples are dodecylbenzene, mesitylene, durene, 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene. Others which did not react with formaldehyde are 1,4-dichlorobenzene, 1,2,4,5-tetrachlorobenzene, 1,2,3,4-tetrachlorobenzene, and nitrobenzene.

Aldehydes—Formaldehyde sources include aqueous formaldehyde (formalin), paraformaldehyde, and dimethoxymethane (methylal). Other aldehydes, such as acetaldehyde, furfural, and benzaldehyde, did not produce the resins.

Resin yields decrease if less than 1.5 moles of formaldehyde are charged per mole of benzene. This is shown in *Figure 2*.

Solvent—Chlorinated hydrocarbons, such as carbon tetrachloride, are the preferred solvents. Various saturated hydrocarbons, such as hexane and petroleum thinner, may also be used; but they thicken excessively during the reaction, making efficient stirring difficult. If no solvent is used, sulfonation of the arene occurs.

Dispersant—The formation of microdispersed formaldehyde-arene resins might be considered an "emulsion resinification." The resin reaction takes place at the sulfuric acid-solvent interface. Many compounds provide the dispersant action necessary to emulsify the sulfuric acid in the solvent. These include polymeric detergents and low molecular weight cationic and anionic detergents. Petroleum sulfonic acids (as the calcium salts) are among the most effective.

Catalyst—Concentrated sulfuric acid is the preferred catalyst because of its low cost and ready availability. At least 4 parts by weight of acid is needed to one of arene if paraformaldehyde is used. At least 8 parts by weight must be used if formaldehyde sources (such as formalin or methylal) which dilute the acid with water or an alcohol are used. This is shown in *Figure 3*. If sulfuric acid of less than 96% strength is used, resin yields decrease markedly as shown in *Figure 4*.

Hydrofluoric acid is as effective a catalyst as sulfuric acid and can be readily removed from the resin by evaporation. HF however, requires special handling and equipment.

Among the by-products of the benzene-formaldehyde reaction are diphenylmethane and higher benzene-methylene condensation products. These are readily removed from infusible resin by solvent wash. Any sulfonation products are also removed by the solvent.

Table 1. Yields of Arene-Formaldehyde Resins

Arene	Resin Yield, g Per 100 g of Arene
PURE COMPOUNDS	
Benzene	105
Toluene	84
o-Xylene	96
m-Xylene	38
p-Xylene	105
n-Butylbenzene	97
Cumene	99
p-Cymene	53
Biphenyl	107
Phenanthrene	132
Chlorobenzene	4
α-Methylnaphthalene	89
Naphthalene	129
Anisole	110
PETROLEUM FRACTIONS	
Light Cracked Gas Oil	42
Light Cracked Gas Oil Aromatics	102
Heavy Xylene Cut	64
Aromatic Solvent (bp 275-335°F)	68
Naphthenic Mineral Oil (2% Aromatics)	2

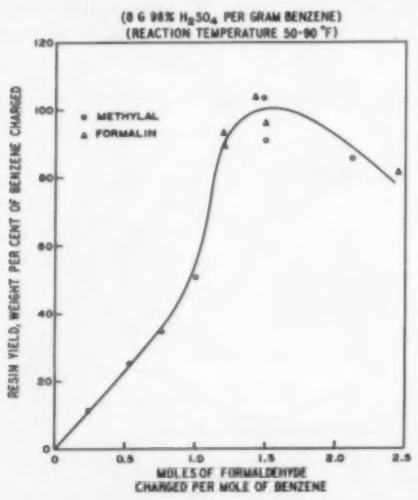

(8 G 98% H_2SO_4 PER GRAM BENZENE)
(REACTION TEMPERATURE 50-90 °F)
METHYLAL
FORMALIN
RESIN YIELD, WEIGHT PER CENT OF BENZENE CHARGED
MOLES OF FORMALDEHYDE CHARGED PER MOLE OF BENZENE

Figure 2. Effect of amount of formaldehyde charged on resin yield. Peak is at 1.5 moles of formaldehyde.

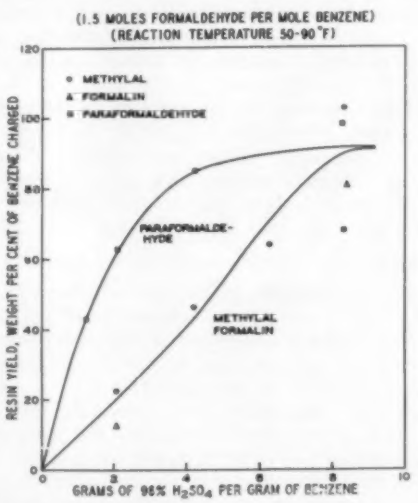


Figure 3. Effect of sulphuric acid amount on resin yield. At least eight parts by weight of acid should be used in this system.

Structure and Mechanism of Formation

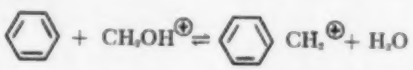
Elemental analyses indicate an empirical formula for benzene-formaldehyde resin of approximately $(C_{13}H_{12}O)_x$. Infrared spectra show the presence of ether linkages. Molecular weights are unknown but are probably high.

We postulate the following mechanism of benzene-formaldehyde resin formation.

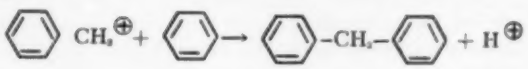
Reaction 1

$$CH_2O + H_2SO_4 \rightleftharpoons CH_2OH^{\oplus} + HSO_4^{\ominus}$$

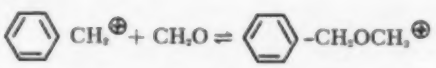
Reaction 2



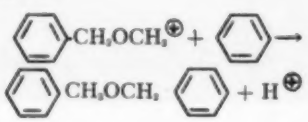
Reaction 3



Reaction 4

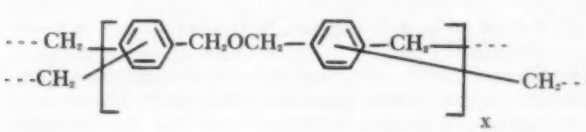


Reaction 5



Both diphenylmethane (from Reaction 3) and dibenzyl ether (from Reaction 5) then react in place of benzene in Reaction 2 to give products which result in high molecular weight crosslinked resins.

The following generalized structure for benzene-formaldehyde resin is proposed:



The above equations explain a number of the experimental results. For instance, arenes with electron withdrawing substituents, such as halogens or nitro groups, will not undergo Reaction 2. Arenes with the 1,2, or 4 positions on the ring blocked cannot form the highly condensed resin structure shown. This would explain the failure of durene (2,3,5,6-tetramethylbenzene) to form infusible resin. Reaction 3 explains the formation of diphenylmethane as a by-product. It also explains why resin yields are low when large excesses of benzene are used. Reaction 2 accounts for the necessity for the use of large amounts of concentrated sulfuric acid. Water formation dilutes the acid during the reaction and reduces catalytic activity. *Figure 4* shows that acid strength must be maintained above 90% for satisfactory resin yields.

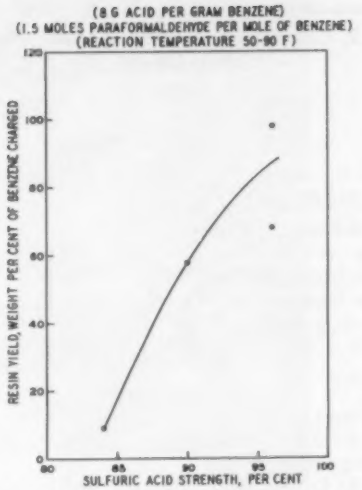


Figure 4. Effect of sulphuric acid strength on resin yield. Below 96% the yield decreases sharply.

Properties

Microdispersed arene-formaldehyde resins are light yellow, talc-like powders. They are stable up to about 700°F in air but sinter and darken above this temperature. They are insoluble in all common organic and inorganic solvents, including boiling concentrated sulfuric acid, but char when treated with fuming sulfuric acid.

The benzene-formaldehyde resin has a surface area of approximately 110 square meters per gram, according to nitrogen adsorption measurements. The individual particles

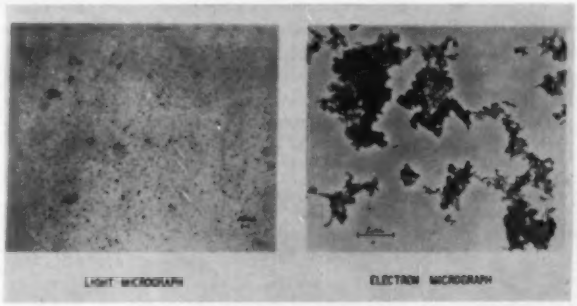


Figure 5. Microdispersed benzene-formaldehyde resin particles.

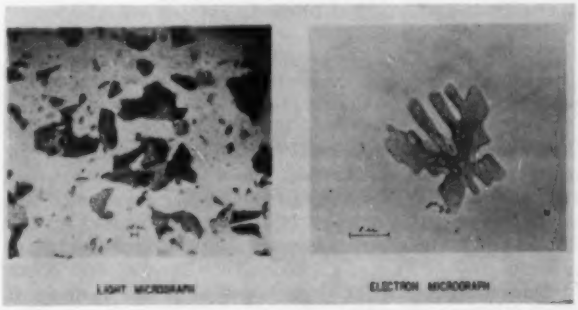


Figure 6. Nondispersed benzene-formaldehyde resin particles.

Table 2. Lubricating Grease Composition and Properties

	Grease A	Typical Soap Base Grease
COMPOSITION		
Benzene-Formaldehyde Resin, Wt %	19.0	—
Calcium Stearate, Wt %	4.0	—
Calcium Hydroxide, Wt %	1.0	—
Naphthenic Mineral Oil, Wt %	76.0	—
PROPERTIES		
Penetration, Worked (ASTM D 217-52T)	297	250-350
Dropping Point, °F (ASTM D 566-42)	580+	200-400
EP TESTS*		
Falex, Lb Load	4200	1500
Four Ball, Kg Load	50	20
Timken Machine, Lb Load	Pass 50	Pass 15 Fail 20
WEAR TESTS*		
Almen Machine, Bronze on Steel, mg Loss	2.0	1-15
Falex Machine, Steel on Steel, mg Loss	1.5	1-30

* For description of tests see "Performance of Lubricating Oils," H. H. Zuidema, Second Edition, Reinhold Publishing Corporation (1959), pp 13-16.

are less than 0.1 micron in diameter but tend to form clusters several microns in size. Light and electron micrographs of the microdispersed resin are shown in *Figure 5*. In comparison, *Figure 6* shows similar micrographs of the porous platelet structure of nondispersed resin.

Uses

Lubricating Grease Gelling Agent—The microdispersed resins are effective gelling agents for mineral oils because of their small particle size, large surface area, and oleophilic nature. One potential use is in lubricating greases. The composition of a typical grease is shown in *Table 2*, along with its performance properties. In this grease, calcium stearate is used as a secondary gelling agent, although satisfactory greases can be prepared from microdispersed resins alone in a mineral or synthetic base oil.

One of the unexpected properties of the resin-thickened greases is high film strength or extreme pressure (EP) behavior. *Table 2* shows that Grease A outperformed conventional soap-based greases in three different types of EP tests and two different wear tests.

Unlike many conventional greases, the high temperature performance of resin-thickened greases is not limited by the melting point of the thickener. The melting points of resin-thickened greases are in excess of 500°F, even when low melting cogellants are used. In high speed bearing tests at 350°F and 10,000 rpm, a mineral oil-based grease achieved a life of 180 hours and a silicone-based grease, 460 hours.

Thickening Agent for Organic and Aqueous Systems—In organic systems the thickening power of microdispersed resin is little affected by the volatility, viscosity, or chemical nature of the fluid. This suggests uses in lacquers, paints, varnishes, inks, putty, and adhesives. In contrast to oleophobic clays, the resins need no coupling agents or surface modifiers.

A wetting agent is needed to make the resins hydrophilic. A mixture of microdispersed benzene-formaldehyde resin (16.6 weight per cent), water soluble nonionic detergent* (0.5 weight per cent), and water (82.9 weight per cent) formed a stiff, yellow-brown paste when passed through a three-roll paint mill. This suggests the use of these resins in creams, emulsions, latex paints, and drilling muds.

Adsorbent—The microdispersed resins can also be used as adsorbents for the treatment of organic liquids. They are useful both in chromatographic and bulk treatments.

Pilot Plant Production

The scale-up from laboratory to pilot plant production of microdispersed resins was readily accomplished. Instead of a glass turbomixer, a double-action, stainless steel grease kettle served as the reaction vessel. An acid-resistant filter was used to isolate the product. The performance properties of the resins were equivalent to those prepared in the laboratory.

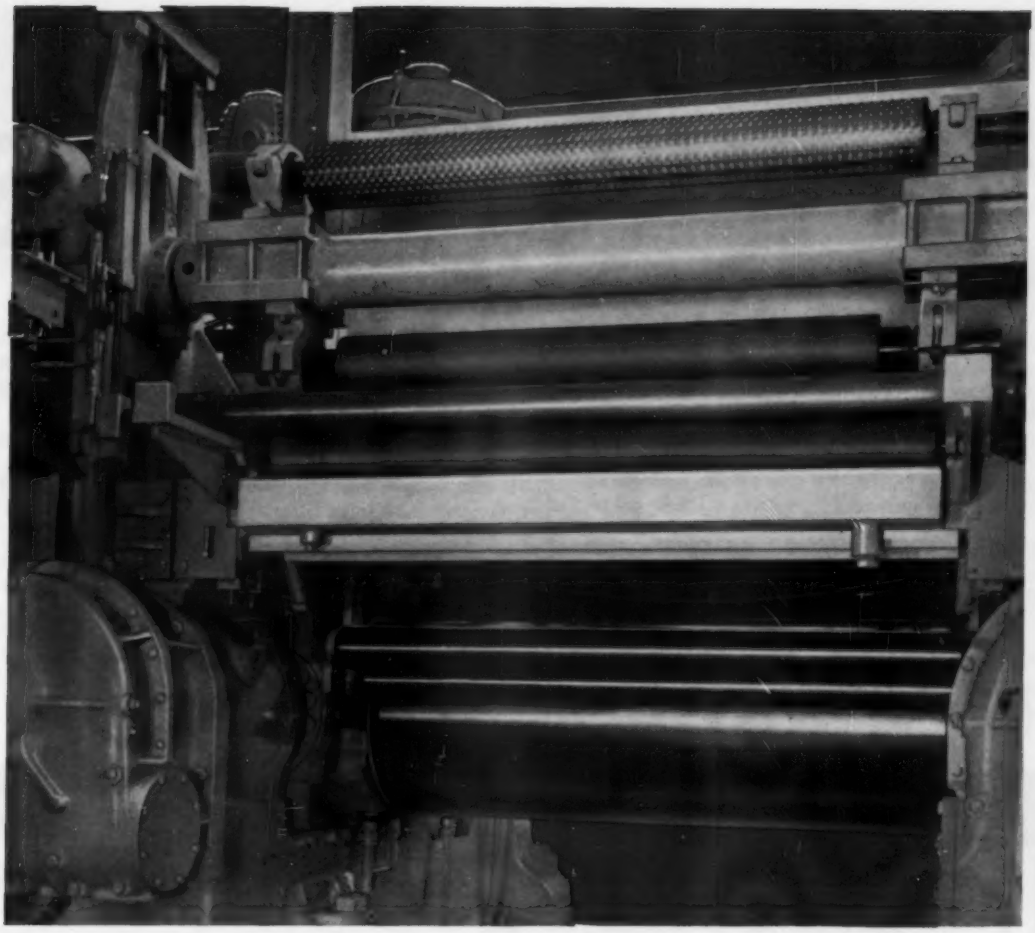
Conclusions

Methods have been developed for preparing microdispersed arene-formaldehyde resins having small particle size and large surface area. Although the nondispersed resins have been known for many years, their preparation in a new form by emulsion resinification techniques makes possible many new uses for the first time. They have been shown to be effective gelling agents for lubricating greases and thickening agents for both organic and aqueous systems. They can be readily prepared from cheap and available raw materials and have potential as commercial products.

* Oronite Dispersant NI-W, a condensation product of ethylene oxide and an alkylphenol.

Literature References

1. Anderson, G. K., Taylor, E. A., and Fishel, J. B., (to The Neville Company) U. S. Patent 2,200,762; U.S. Patent 2,200,763, May 14, 1940.
2. Badertscher, D. E., and Bishop, R. B., (to Socony-Vacuum Oil Company) U.S. Patent 2,397,398, March 26, 1946; U.S. Patent 2,477,538, July 26, 1949.
3. Feasley, C. F., (to Socony-Vacuum Oil Company) U.S. Patent 2,501,600, March 21, 1950; U.S. Patent 2,660,-572, November 24, 1953.
4. Fulton, S. C., and Gleason, A. H., *Ind. Eng. Chem.* 32, 304 (1940).
5. Gleason, A. H., (to Standard Oil Development Company) U.S. Patent 2,216,941, October 8, 1940.
6. Gordon, L. B., and Kelly, J. T., (to Pan American Refining Corporation) U.S. Patent 2,713,571, July 19, 1955.
7. Gordon, L. B., May, P. D., and Lee, R. J., *Ind. Eng. Chem.*, 51, 1275 (1959).
8. May, P. D., and Lee, R. J., (to Pan American Refining Corporation) U.S. Patent 2,597,159, May 20, 1952.
9. Nastyukov, A. M., *J. Russ. Phys. Chem. Soc.*, 35, 824 (1903); abst *J. Chem. Soc.*, 86, 242 (1904).
10. Nastyukov, A. A., *J. Russ. Phys. Chem. Soc.* 36, 881 (1904); abst *J. Chem. Soc.* 86, 801 (1904).
11. Thompson, K. M., (to The Atlantic Refining Company) U.S. Patent 2,382,184, August 14, 1945.
12. Woolhouse, T. G., and Lunn, W., U.S. Patent 2,568,313, September 18, 1951.



This plastics calender is one of the most versatile ever built

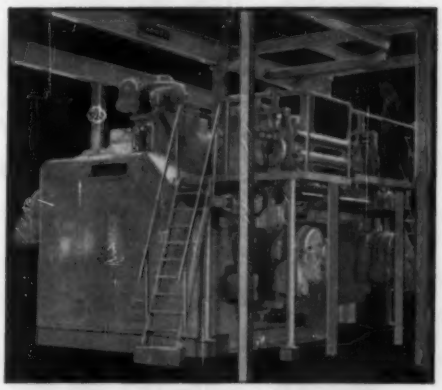
The Farrel calender pictured here was built for a company that processes a variety of plastics products. The machine will produce the full range—from the thickest sheeting to the thinnest film.

Contributing to its versatility is the new automatic turret embosser, shown above, which is designed to take all of the customer's existing rolls plus those to be used in the future. Two embossing rolls are carried in the turret. Either may be brought to the ready position within ten seconds by pushing a button—without breaking the sheet.

The calender, itself, is a 500°F Uni-drive machine, with an independent drive for the number 4 roll and a maximum delivery speed of 110 yards per minute. Operation at high temperatures under heavy loads is made possible by a special sleeve-bearing design.

Great attention has been given the lubrication system which uses twin pumps mounted in parallel for individual push-button operation. Other features include such well-known Farrel developments as two-speed motorized roll adjustment, motorized guides and the cross-axis device.

Discover for yourself how Farrel engineering pays off in calendering quality and versatility. Ask to see a Farrel engineer.



FARREL®

FARREL-BIRMINGHAM COMPANY, INC.
ANSONIA, CONNECTICUT

Plants: Ansonia and Derby, Conn., Buffalo and Rochester, N. Y.
Sales Offices: Ansonia, Buffalo, Akron, Chicago, Los Angeles, Houston, Atlanta
European Office: Piazza della Republica 32, Milano, Italy

FB-1214

New from Emery Research

4 New Polymerics

Emery research has achieved a significant breakthrough in the field of polymeric plasticizers. Four new polymerics have been introduced to complement Plastolein 9720, the industry's largest selling polymeric. Together, they now give you a single source for a wide range of your plasticizer needs. Although Plastolein 9720 will continue to be the choice in uses demanding its ease of processing and low viscosity, the four new plasticizers meet other needs:

Plastolein 9722: An improved version of Plastolein 9720 in humidity and outdoor aging, compatability, extraction and migration—at the same low cost. (Formerly Emery 3282-D)

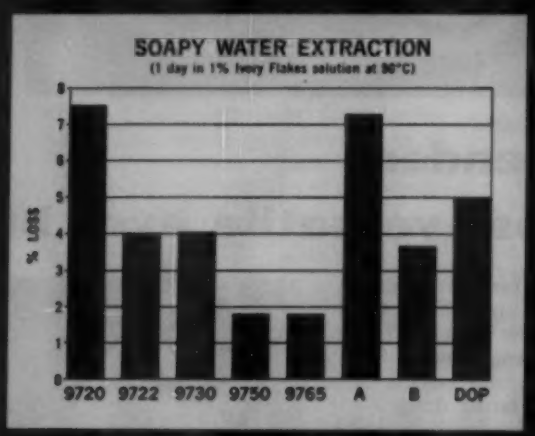
Plastolein 9730: Now, the lowest cost polymeric plasticizer featuring low migration properties, excellent outdoor stability, and good soapy water resistance. (Formerly Emery 3311-D)

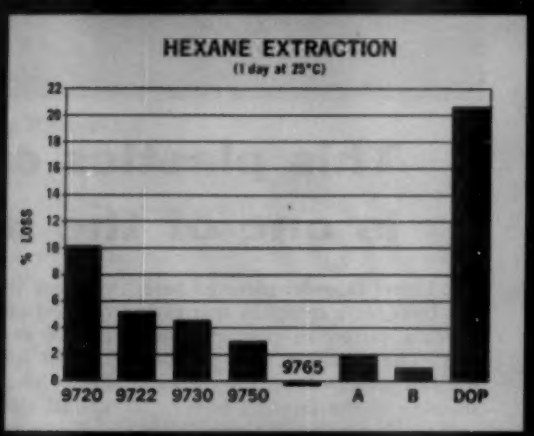
Plastolein 9750: A good, general-purpose, medium molecular weight polymeric at low cost, with excellent soapy water extraction and outdoor stability. (Formerly Emery 3313-D)

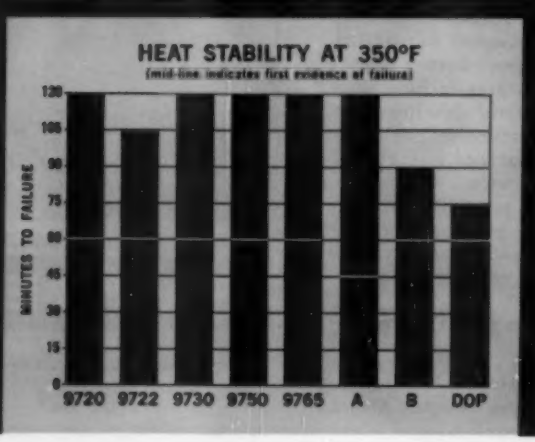
Plastolein 9765: The medium molecular weight polymeric plasticizer offering the best all-around permanence. Its cost is low, humidity aging outstanding, and extraction resistance tops. Special deodorized grade available. (Formerly Emery 3314-D)

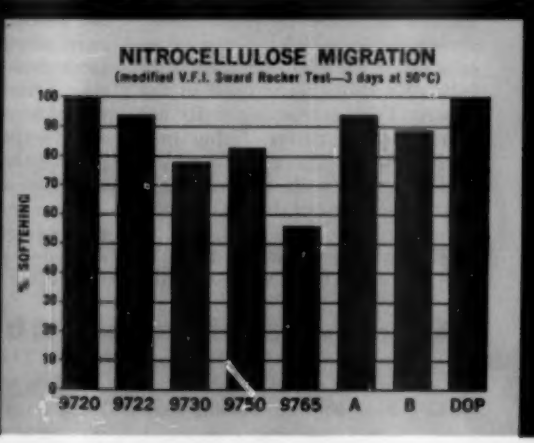
Extensive aging tests have been conducted by the South Florida Test Service. The Emery polymerics were compared with two leading competitive plasticizers and with DOP. Results show outstanding superiority of the Plastolein polymerics. Full information on the new Plastolein Polymeric Plasticizers including reproductions of test samples is available in Technical Bulletin 424. Write Dept. J-7.

Check Plastolein Polymeric performance on eight









now the most complete line of low cost polymeric plasticizers in the industry

join famous Plastolein® 9720

POLYMERIC PLASTICIZERS FOR MANY USES

	PLASTOLEIN 9720	PLASTOLEIN 9722	PLASTOLEIN 9730	PLASTOLEIN 9750	PLASTOLEIN 9765
Coated upholstery fabrics	●	●	●	●	●
Unsupported films	●	●	●	●	●
Baby wear	●	●	●	●	●
Wall coverings	●	●	●	●	●
Vinyl-metal laminates	●	●	●	●	●
Industrial tapes		●	●	●	●
Shoe constructions	●	●	●	●	●
Surgical tapes				●	●
Plastisols, organosols	●	●	●	●	●
Coated paper	●	●	●	●	●
Pigment grinding	●	●		●	●
Refrigerator gaskets					●
Flooring	●	●	●	●	●
Hospital sheeting					●
Crash pads				●	●
Vinyl foam	●	●	●		

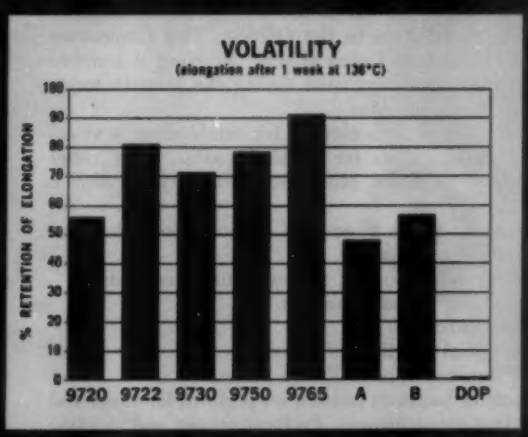
Emery

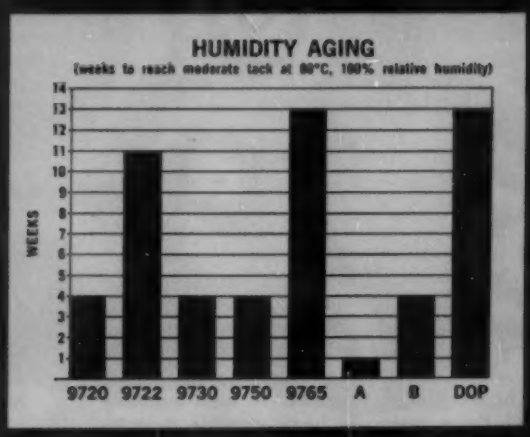
EMERY INDUSTRIES, INC.
Organic Chemicals Division
Carew Tower, Cincinnati 2, Ohio

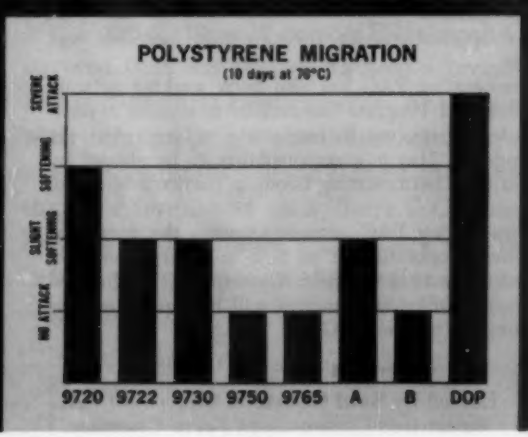
Vopcolene Division, Los Angeles, Calif.,
Emery Industries (Canada) Ltd., London, Ontario,
Export Division, Cincinnati, Ohio

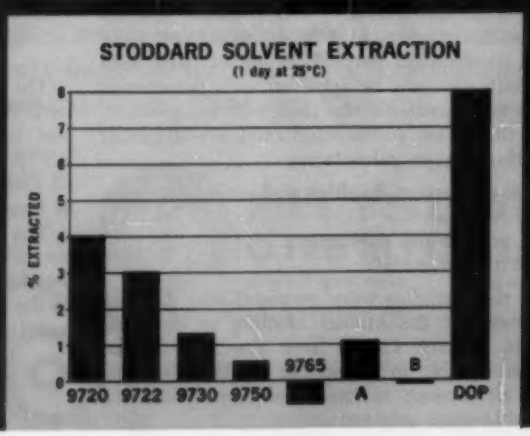
important properties against two leading competitors

Polymeric Performance At Efficiency Concentration (Modulus = 1300 ± 100)









Ross H. Dean, *Chairman*
Thermosetting Molding PAG (Sterling, Inc.)

PAG Progress

Thermosetting Molding PAG Continues to Expand Activities and Membership

The Thermosetting Molding PAG, in keeping with the policies of SPE in organization of Professional Activity Groups, is established for the purpose of developing, collecting and disseminating engineering data and technical information of benefit to engineers, molders and others working in and with the thermosetting field.

The thermosetting area of the plastics industry, while perhaps not as recognized in recent years for its spectacular growth and development as other phases of plastics, has shown sound progress in the development of new equipment, techniques, materials and products. The Thermosetting Molding PAG has likewise grown in its activities and membership and is continuing to expand. The professional growth of its members and the increased collection and dissemination of technical information to SPE membership as a whole are reflected in the increased interest in this PAG.

As a result of research and development during the last few years, the thermosetting field appears to be started on a new phase of progress which could see new materials, new applications and new processes move ahead with rapid strides to match the growth of other plastics. Concentrated work with phenolics, alkyds, diallyl phthalates, epoxy materials and silicon molding compounds has been particularly noticeable in the electronic field where the exotic materials now are providing the essential characteristics so necessary for performance under extremely critical conditions.

Resistance to higher temperatures and to high humidity which certain of these materials have, provide features desirable to the electrical industry. The pressure benefits available with the use of epoxy materials offer opportunities for new designs in electrical parts. Forming of parts with delicate components can now be achieved with the epoxies thereby opening new areas for the design of components.

During 1960 three task forces conducted investigations and studies on three major subjects:

1. Electronic preheaters, finishing and accessory equipment.
2. Molding presses and preformers.
3. Thermosetting materials.

Summaries of these studies were prepared and distributed to those present at the Annual Meeting of the PAG in Washington in January. Copies have also been mailed to those who were unable to attend the meeting but who have expressed an interest in these subjects. Additional copies are available upon request.

The reports were factual, complete and helpful to engineers since they provided current summaries—some in tabulated form—of specifications and data not ordinarily available in such a concise manner.

The annual meeting of the Thermosetting Molding PAG featured a presentation by Dr. A. N. Howald who discussed the Injection Molding of Thermosetting Materials. Attendance at this meeting was the largest experienced by the Thermosetting PAG in many years. The illustrated presentation of the rather unique subject was well received and provided material for further consideration by those present.

The Executive Committee of this PAG was expanded in January to 13 in addition to the Officers. This Committee through individual task forces is now studying a number of subjects which were suggested during the January meeting. Some of these include:

1. Determination of a method for establishing a visual inspection criteria for molded parts. What other approach is there other than comparison with a standard part?
2. Effect of various fillers and reinforcements in thermosetting materials.
3. Uniformity of flow of thermosetting materials.
4. Preforming of fine powders.
5. Epoxy molding.
6. Mechanical handling of powders.
7. Post forming of cross linked materials.
8. Effects of moisture content on preform hardness and molding consequences. Preform shapes and molding consequences.
9. New applications for thermosetting materials and parts.

The Thermosetting PAG has also been working actively with the Technical Program Committee to obtain, review, and up-grade papers on thermosetting subjects for the ANTEC program. This is a responsibility to be shared by all PAGs and the Thermosetting Group is particularly aware of its part.

The Thermosetting PAG earnestly invites the participation and active cooperation of all SPE members who have activities and interests in this field. Correspondence directed to the Executive Office at Stamford will be forwarded and handled promptly by the PAG.

—— ■ ——

Edited by **Saul Gobstein,** *Chairman PAG Executive Committee (Ferro Chemical)*

PX-104 DiButyl Phthalate PX-108 Dilso Octyl Phthalate
PX-114 Decyl Butyl Phthalate PX-118 IsoOctyl Decyl Phthalate
PX-120 Dilso Decyl Phthalate PX-126 DiTriDecyl Phthalate
PX-138 DiOctyl Phthalate PX-314 N-Octyl N-Decyl Phthalate
PX-914 Butyl Octyl Phthalate PX-208 Dilso Octyl Adipate
PX-212 N-Octyl N-Decyl Adipate PX-220 Dilso Decyl Adipate
PX-238 DiOctyl Adipate PX-404 DiButyl Sebacate PX-438 DiOctyl Sebacate
PX-800 Epoxy PX-917 TriCresyl Phosphate

"Pittsburgh Chemical makes too dog-gone many plasticizers!"

Mr. Puppy, the only reason Pittsburgh Chemical makes so *many* plasticizers is because we've discovered that our customers *need* a broad variety to match their umpteem compounding problems and end-product requirements. And, nine times out of ten, Pittsburgh Chemical "comes through" with an appropriate plasticizer solution.

If you're producing vinyl plastics in any way, shape or form, give us a "bark." Chances are, Pittsburgh Job-Rated Plasticizers will be able to help you produce an even better end product —at lower cost.

INDUSTRIAL CHEMICALS DIVISION
PITTSBURGH CHEMICAL CO.
GRANT BUILDING PITTSBURGH 19, PA.
A Subsidiary of PITTSBURGH COKE & CHEMICAL CO.

3347

CALL YOUR NEAREST PITTSBURGH CHEMICAL SALES OFFICE . . . PITTSBURGH, NEW YORK OR CHICAGO

SOCIETY ACTION

Mid-Year Progress Report

Frank W. Reynolds, *SPE President*
(International Business Machines Corp.)

Gratifying progress has been made toward the goals we set in January during the first half of our administrative year.

The following report highlights action taken at 32 Committee Meetings held since ANTEC, including 12 meetings held in New York City during the SPI National Plastics Exposition from June 5 to June 10.

SPE Co-sponsors USIA Exhibit—The SPE is co-sponsor with the SPI of the United States Information Agency "Plastics in America" Exhibit now touring Russia. SPI is the other co-sponsor. This participation includes administration of a $56,000 Government Grant. The SPE name and emblem appears on 350,000 copies of the Exhibit pamphlet distributed throughout Russia.

Past Presidents Advisory Board—SPE's new International Award in Plastics Science and Engineering is being implemented by formation of Award and Canvassing Committees; designing the medal; and publishing a brochure. Procedures for review and selection of SPE Distinguished and Honorary Membership have been established.

The Ad Hoc Committee to Study the Desirability of Engineering Displays has developed a specific proposal for SPE Engineering Displays concurrent with technical conferences for submission to Council at its October 9 meeting.

Engineering and Administrative Boards—Both new Boards have demonstrated completely their value in coordinating activities of SPE Committees and in improving communications among them. The Boards have lifted much of the load from these previously overtaxed bodies by resolving policy matters for recommendation to Executive Committee and Council.

Professional Activity Group Executive Committee has initiated a quarterly PAG Newsletter reporting activities of SPE's 16 PAG's; defined its Committee responsibilities; cooperated with the Technical Program Committee by arranging for PAGs to review abstracts of technical papers; and expanded Section PACs and PAG-programmed RETECs.

The Traveling Educational Exhibit sponsored by the Plastics in Buildings PAG opened successfully in Springfield, Mass. on April 20. It will be shown in 15 other North American cities during the next two years.

The Education Committee has published its revised brochure, "Engineering Education in Plastics", and will soon publish a list of over 300 publications in the polymer field in the SPE Journal. Subcommittees have been formed to cover adult education courses; trade and high-school courses; and academic programs.

The Inter-Society Relations Committee has initiated a program to secure reports of technical and administrative activities in sister societies of interest to SPE members from its liaison members and publish them in the SPE Journal. The SPE has applied for affiliation with the American Society for the Advancement of Science.

The Plastics Institute Committee has incorporated the Plastics Institute of America in the State of South Carolina as a non-profit organization. PIA is planning to employ its own Executive Secretary, and 70 universities have been surveyed for location of the Institute. In the meantime PIA expects to start research activity by awarding contracts to one or two universities.

Meetings Committee—Award of the 1966 ANTEC to the Quebec Section to be held in Montreal, and of the 1967 "Silver Anniversary" ANTEC to the Detroit Section where the Society was founded, has been approved by Council letter ballot. Five Sections have petitioned for spring 1962 RETECs.

The Technical Program Committee is off to a fine start in its first year of operation, and is meeting the ambitious schedule that it set for itself. Authors of 117 of the 168 abstracts received by April 15 have been requested to complete their papers by August 1 for review.

Publications Committee—SPE Transactions has over 1.000 subscribers and is paying its way during its first year. Specific proposals for a new publication and for an abstracting service for the SPE membership will be submitted to Council in October.

Editorial Advisory Board—In addition to reviewing papers for the SPE Journal and Transactions the EAB also reviews papers submitted for presentation at ANTECS. To do so more effectively, it has expanded its membership from 16 to 22. The EAB employs the active assistance of SPE's 16 PAGS.

Technical Volumes Committee—Four volumes are in process. Twenty-five authors are at work writing twenty one chapters of "Engineering Design for Plastics," scheduled for completion in 1962. "Processing of Thermoset Resins," "Molecular Engineering of Plastics Materials," and "Mold Design" are in earlier stages of development.

Finance Committee—A revised 1961-1962 budget totaling $475,746.75 has been approved by Council letter ballot, and $37,481.00 is budgeted to be added to surplus and reserve. ANTEC Company Registration and RETEC

procedures have been revised to produce an estimated $8,000.00 of new income. A more equitable formula for payment of rebates to Sections has been adopted by letter ballot of Council. As a result of economies made following ANTEC, the Society operated in the black in the 1960-1961 fiscal year.

Constitution and By-Laws Committee has revised SPE's Constitution, By-Laws and Rules to add a dissolution clause; to permit Past Presidents to serve a second year on Council and Executive Committee; and as required to implement SPE's new management organization. The constitutional amendments were adopted by an overwhelming ballot of SPE membership counted on June 19.

The Nominating Committee has completed the slate of candidates for 1961 SPE Officers which will be mailed to Council in advance of its election meeting in Detroit on October 9, and the Election Inspectors Subcommittee is organized to implement the election.

The Public Relations Committee has completed its organization of 23 Regional Public Relations Advisors to assist Sections and staff. SPE's PR Program includes information services to publications; news releases on Society activities; a special ANTEC publicity program; assistance to RETEC and Section Publicity Chairmen; and publication of the SPE Annual Report.

Membership Committee—There were 9289 members in good standing on May 31, 1961. The 1961 inter-Section membership contest has been made more equitable by dividing it into two groups —Sections of over 200 members and Sections of less than 200 members. The Student Membership Subcommittee distributed a Student Membership Guide to Sections to assist them with their student programs.

The Credentials Committee has developed a Manual of Procedures to define accurately the requirements for various membership grades, and has been instrumental in expediting processing of membership applications.

The New Sections Development Committee—Three new groups, Mid-Michigan, Rock Valley, and Delaware Valley, have already met SPE's requirements and will petition Council at its October meeting for Section Charters. A revised Manual of Procedures for New Section Development has been completed.

The Sections Committee is revising its Manual of Procedures.

Executive Office has installed a job and personnel evaluation system, and has revised the layout and redecorated its office to utilize its space more effectively and to improve its appearance.

—— ■ ——

edited by **Thomas A. Bissell,**
SPE Executive Secretary

NEW BOOKS

VISCOELASTIC PROPERTIES OF POLYMERS

by John D. Ferry, University of Wisconsin (John Wiley and Sons, Inc., New York, 1961, 482 pp., $15.00)

It is indeed an exhilarating experience to read a scientific work on a subject where the author is a foremost authority. Such is the case with this book. It summarizes in a coherent and precise fashion much of the author's own research. It furthermore presents the most complete analysis of polymer viscoelasticity which has appeared to date. The treatment is based on the principle of superposition where time, temperature and concentration variables are normalized by the method of reduced variables. The book may be arbitrarily divided into four sections: (1) basic theory of viscoelasticity; (2) experimental techniques; (3) molecular origin of viscoelasticity and (4) physical states of polymeric materials.

The first four chapters cover the underlying theory of the viscoelastic behavior of isotropic polymer systems. The phenomenological point of view is used throughout. Chapters 5 through 9 describe experimental techniques for studying the dynamic mechanical properties of polymers. This comprehensive section treats low frequency tests (creep and stress relaxation) as well as techniques utilizing pulse propagation (ultrasonics). The gamut of intermediate frequencies is also included. Methods for studying viscoelastic liquids, and soft and hard polymers are discussed along with special devices for determining bulk moduli and for assessing fiber properties. The next three chapters are devoted to the molecular theory of viscoelasticity. Here the origin of the glass transition is treated in exhaustive detail. Both the free volume concept and the monomeric friction coefficient approach are considered. Chapters 13 through 18 summarize the essential features of the rubbery and glassy states. In addition, crystalline and filled polymers are treated in the light of theoretical and experimental arguments. Next, concentrated solutions, including plasticization are discussed. A review of the viscoelastic properties of polymer gels is then presented followed by a summary of work reported in the area of bulk deformation.

The last chapter presents a subject of great potential interest to the plastics engineer. Here illustrative examples of viscoelastic calculations are given. Model calculations are given in which viscoelastic data are used to make rough predictions as to the mechanical behavior of polymers under widely different conditions of temperature, plasticization and other variables.

The subject matter of this book is not presented in a form suited to ready adoption by the plastics technologist. However, many useful data about the dynamical mechanical properties of specific systems are given, and the approach used undoubtedly represents the future trend in interpreting polymer properties.

The different chapters require varying degrees of mathematical sophistication. In general, I would recommend the book to the research worker rather than to the plastics engineer. The complete bibliography of the literature on the viscoelasticity of polymers will prove useful to anyone working in the plastics field.

It is my opinion that this book is destined to become a classic work in the field. Finally, it is felt that a thorough familiarity with the principles of viscoelasticity herein presented would do much to improve the understanding of polymer processing. Furthermore, it would aid in putting the field of polymer processing on a firmer scientific foundation.

Dr. Armand F. Lewis
Central Research Division
Stamford Research
Laboratories
American Cyanamid Company

DOW PLASTICS TECHNICAL FILE

MELT STABILITY AND FLOW SENSITIVITY OF MOLDING MATERIALS

Advanced molding techniques often require a knowledge of a plastic molding material's stability at higher-than-normal operating temperatures. Since it is essential to operate under conditions which will not degrade the material, both melt stability and flow sensitivity at various fabrication temperatures are of prime importance.

The sensitivity of melt flow to temperature changes is of particular interest when determining optimum molding cycles for new materials. With the proper data, it is usually possible to select a temperature for the new material which will give flow behavior comparable to that of a known material. This provides a useful starting point for characterizing new polymers.

The temperature-viscosity relationship also indicates the degree to which stock temperature must be controlled during fabrication. A sensitive material, for example, will exhibit widely varying flow with small changes in machine temperature. Where the proper data are available, and properly interpreted, it is possible to change quickly from one material to another with a minimum of lost machine time and rejected parts.

By means of a capillary type plastic viscometer, Dow thermoplastics have been evaluated under varying conditions. This apparatus makes it possible to hold materials at known stock temperatures for extended periods of time. Melt viscosity is measured by forcing the plastic through a capillary at a shear stress comparable to that expected during fabrication.

A study of viscosity as a function of time at a constant temperature and shear stress indicates the thermal stability of the plastic melt. Melt viscosity at varying temperatures indicates the viscosity-temperature sensitivity of the material.

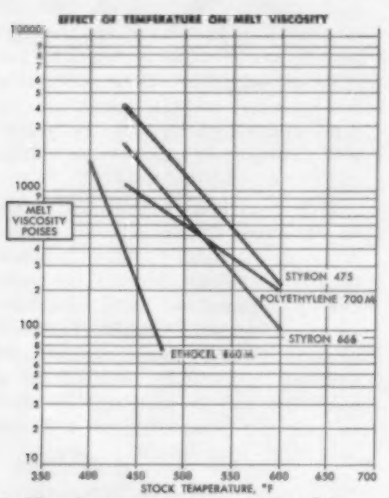
The data in Graph I indicate the sensitivity of the melt viscosity of ethylcellulose to temperature change. Polystyrene and its copolymers are intermediate, while polyethylenes are the least sensitive of the three.

Graph II shows melt stability of Styron 440 at various temperatures. Initial degradation at 550°F. is indicated by a slight drop in viscosity during the one-hour test period. At 600°F., a serious drop in viscosity is found. It would not be advisable to hold stock temperatures of this material at this level for any appreciable time. (In practice, stock and machine temperatures may differ widely. In injection molding, for example, the cylinder temperature may exceed the stock temperature by 100 to 150°F. where short cycle times are used.)

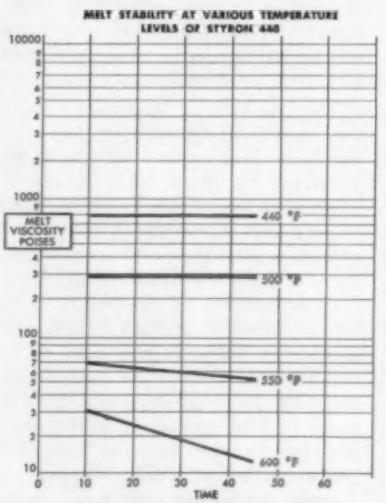
Degradation temperature levels for some typical materials are given below. Slight degradation is noted at the lower temperatures, and becomes more pronounced as temperatures increase.

AMERICA'S FIRST FAMILY OF THERMOPLASTICS

Styron® • Polyethylene
Zerlon® • PVC Resins
Ethocel® • Pelaspan®
Tyril® • Saran



I. Viscosity-temperature sensitivity of four Dow thermoplastics.



II. Melt stability of Styron 440.

TABLE 1

Degradation temperatures

Material	Range, °F.
Polyethylene, all densities	600-650
Styron	550-600
Tyril	550-600
Zerlon	500-525
Ethocel	425-450

Because of the continuing studies by Dow Plastics Technical Service engineers, considerable data on melt stability and flow sensitivity of thermoplastics are available. Designers and plastics engineers are invited to contact Dow for more detailed information. Write Molding Materials, Plastics Sales Department 1734EX7.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

SECTION NEWS

Northwest Pennsylvania

Injection Molding Machines

LLOYD ENGLISH
(Louis Marx Co., Inc., Penna.)

A dinner meeting attended by 50 members and guests was held at the Penn Laurel Hotel in Warren, Pa. on May 25. Mr. William G. Kriner, sales manager of HPM Division of Koehring Company spoke on new developments in plastic injection molding machines.

The new officers elected by the section were announced as follows:

President—Francis M. Tirpak
Vice President—George Shau
Treasurer—Francis B. Richardson
Secretary—Charles R. Sturtevant

Milwaukee

Fluidized Bed Coatings and Applications

C. H. STRONG
(Union Carbide Plastics Company)

Fifty-five members and guests of the Milwaukee Chapter heard an excellent talk on fluidized bed applications by Mr. M. V. Rothschild of Armstrong Resins, Inc., Warsaw, Indiana. He defined fluidized beds, discussed equipment involved, and what is needed for proper application, how it is applied, and showed many samples.

New officers for the year of 1961-62 were announced as follows:

President—James S. Herons, Owens-Corning Fiberglas Co.
Vice President—William G. Murray, A. O. Smith Corp.
Treasurer—James A. Murphy, Cadillac Plastics Co.
Secretary—Daniel E. Grzegorczyk, AC Spark Plug Div. of General Motors

Rochester

Spring Cruise

JOHN T. BENT
(Eastman Chemical Products Inc.)

On Saturday, April 29, a highly successful "Spring Cruise' was held at Logan's.

Mr. Richard Melville and Mr. Raymond Cruse, Co-Chairmen of the annual event worked hard in preparing and planning this outing.

Central New York

First Student Night

JOHN A. MEYER
(Syracuse University)

Last Fall members of the Central New York Section Board voted to sponsor a student night in the Spring where students would be invited from local high schools and colleges. Responsibility of organization was given to the Education Committee.

It was suggested that each member interested in participating would act as host for one high school student and that he would take the student with him to his place of employment during the afternoon preceding the meeting. At the end of the day the member would then bring the student to the local section meeting for dinner and the following technical talk. The college students however, were invited to attend the section dinner meeting only. Nine high school students and eleven college students would be invited to attend the monthly section meeting.

Parental permission for the participation of the high school students was required before these students could be excused from their regular classes for the half day to accompany the section members on the plant visits.

The plan received enthusiastic approval from the Principal and Chemistry Department Head at Central Technical High in Syracuse. Parents were also very receptive and the students displayed significant interest at the meeting.

The most successful part of the program was the visit to the various plants and laboratories and the college students expressed their disappointment in not being included in the on-the-job visits. The number of students who can be accommodated on plant visits depends upon the willingness of the membership to act as hosts. Next year it is hoped that more of the members will be able to cooperate and that we will be able to provide all the invited students with an opportunity to visit one of the local plants or laboratories.

Ontario

Pennant Raised

H. A. SHURE
(Naugatuck Chemicals)

There were 63 persons at the May 18 meeting in Toronto. The highlight was the presentation of the Iroquois Region pennant by Councilman Maurice Malone to Ontario Membership Chairman Omer Wilson as a symbol of their victory in achieving a record membership in the Region.

"The Marketing Challenge of the 60's" was the subject of the talk given by Mr. Frank G. Rice (DuPont of Canada Ltd.) He described the competition involved and the work required for future market growth in Canada.

Election results were made known at the Society's meeting in Toronto last month by retiring president Harry Watson, Canadian Plastics magazine editor. President elect is John "Mack" Lees, C.G.E., custom molder, Cobourg, Ontario. Vice President is Earl Lince, Smith and Stone, custom molder, Georgetown, Ontario; Treasurer is Don Halbert, F & H Plastics, custom molder, Scarboro, Ontario. Secretary is Omer Wilson, Accurate Mould, tool maker, Rexdale, Ontario.

Kentuckiana

Rotational Molding

GEORGE A. POLK
(General Electric Co.)

Union Carbide Plastics Co. presented the program at the May meeting of the Kentuckiana Section. Larry A. McKenna was guest speaker. His illustrated talk covered materials used in this centrifugal casting process, equipment and tooling required, and advantages of the process in various applications.

Miami Valley

Cost Savings in Metal Removal

ROGER A. HOUSTON
(Recto Molded Products, Inc.)

The Miami Valley Section was particularly fortunate in having two prominent men in the plastics field address its May 4 meeting at the Wishing Well in Centerville—Dr.

GOOD LOW-TEMPERATURE PROPERTIES
with FLEXOL epoxy plasticizer EP-8

Want good performance in your vinyl film at low temperatures? Specify CARBIDE's FLEXOL EP-8 — the highest-purity, low-temperature epoxidized plasticizer-stabilizer commercially available.

FLEXOL EP-8 (2-ethylhexyl epoxy tallate) gives good flexibility at temperatures as low as −40°F., and without premium price. Low-temperature properties of this material are comparable to more expensive adipate, azelate, and sebacate plasticizers.

High oxirane oxygen content and low iodine value make EP-8 outstanding for compatibility and sunlight stability.

Compounding versatility and plasticizing efficiency of EP-8 are ideal for convertible car tops and seat covers, high-clarity film and sheeting, garden hose, and electrical insulation. EP-8 is also useful as a viscosity depressant and stabilizer for plastisols and organosols.

Film manufacturers gain another important economy from EP-8's low viscosity and low molecular weight. Calendering mills can run through *more pounds of vinyl resin per hour* because of faster solvating and better fluxing of vinyl resins by EP-8.

Ask your CARBIDE Technical Representative for details on FLEXOL EP-8's interesting properties and money-saving, material-replacing advantages—available in shipments from drums to tank cars. Or write: Union Carbide Chemicals Company, Division of Union Carbide Corporation, Dept. HX, 270 Park Avenue, New York 17, N. Y.

UNION CARBIDE CHEMICALS COMPANY

UNION CARBIDE

FLEXOL and UNION CARBIDE are registered trade marks

M. Eugene Merchant, Director of Physical Research for the Cincinnati Milling Machine Company, and Mr. John M. Berutich of Louisville, Ky., treasurer of National S.P.E.

Dr. Merchant's presentation of the basic causes of present day high machining costs and the physical means of combatting them was documented by micro-photo movies showing actual milling microscopic action pictures of cold metal flow and resistance and methods of reducing excess energy.

Mr. Berutich, SPE's national treasurer, explained many of National's problems and plans tying in its aims with those of the local level.

The following new Directors were elected for the ensuing term—John E. Barron, President, Chemplasco, Inc., Cincinnati, O.; Richard W. Bice, Mold Engineer, Formica, Inc., Cincinnati, O.; Earl D. Sumner, Plastics Lab. Mgr., Duriron Corp., Dayton, O.

Newark

Newark Announces New Officers

R. E. CHRISTENSEN
(Union Carbide Plastics Co.)

At the regular monthly meeting on May 10, President Al Spaak announced the Newark section officers for the next year. They are: Bud Merrill, President; Jim Fogarty, Vice President; Bob Bostwick, Secretary, and Si Bodner, Treasurer.

The program consisted of two concurrent sessions, one on epoxy resins and the other on equipment and processing. Mr. Walter Henson of Dow Chemical Co. spoke on "New Advances in Epoxy Resins" and Mr. W. C. Eisenhard of Wallace & Tieman, Belleville, N. J., spoke on "New Advances in Epoxy Resin Curing Agents" in the epoxy session.

In the equipment and processing session, one talk dealt with extrusion and the other with injection molding. Mr. Norton Wheeler of Davis Standard Co., Mystic, Conn. spoke on the pressure and temperature variations which occur in extrusion under various operating conditions and with different materials.

President Al Spaak of Grace Chemical Co. stepped in as a last-minute replacement for the scheduled speaker who was unavoidably absent, and presented an excellent discussion on the fundamentals of injection cylinder design and performance.

Connecticut

Granulated Wood Molding

KENNETH G. CLARKE
(E. I. du Pont de Nemours & Co., Inc.)

The May meeting of the Connecticut Chapter featured as guest speaker Mr. F. J. Donohue of Monsanto Chemical Company, Springfield, Massachusetts, who spoke on "Granulated Wood Molding".

Mr. Harlan Fisher of Watertown Manufacturing Company, Watertown, Connecticut, Section President, announced the election of new officers for the coming year. They are: President—Ralph Eposito of the W. S. Rockwell Company, Bridgeport; Vice President—Mr. Clifford Robinson of American Cyanamid Company; Treasurer—Mr. P. P. Paulishak of the General Electric Company, Bridgeport; Secretary—Mr. Henry Mastriano of the Patent Button Company, Waterbury.

St. Louis, Mo.

Lustran I, SAB Terpolymer

RICHARD H. KOEHRMANN
(International Shoe Company)

The May 15 meeting of the St. Louis Section of SPE was held at Holiday Inn, South. Mr. Stan R. Melvin of Monsanto Plastics Division spoke on Lustran I, the family of SAB terpolymers recently announced. The properties and applications were shown and the market relationship of this family of terpolymers to existing polymers was discussed.

Akron, Ohio

New Section Officers Elected

GEORGE REESMAN
(Rubbermaid, Inc.)

The new officers for the 1961-62 year are:

President: Mr. Foster Young—Goodyear Research

Vice President: Mr. Merle Sanger—General Tire

Secretary: Mr. Donald Siddel—U.S. Stoneware Co.

Treasurer: Mr. Richard Senn—National Rubber Machinery

Plans are under way to sponsor a course in "Plastics Technology" at the University of Akron for the Fall term, 1961.

Kentuckiana

Color

GEORGE A. POLK
(General Electric Co.)

Mr. Roy Hill of the Eastman Chemical Products, Incorporated, spoke on "Color and Color Concentrates" at the April meeting.

Mr. Hill first presented an interesting introduction to the physics of color, color specifications and classifications. This was followed by an explanation of the application of color concentrates and handling hints.

Cleveland

Cleveland SPE Holds Monthly Meeting

E. K. McCLELLAN
(Eastman Chemical Products, Inc.)

The last technical meeting of the year of the SPE Cleveland Section was held Monday, May 15, at Pesano's Restaurant, Cleveland, Ohio. There were 62 members and guests on hand to hear Mr. Arthur J. Wiltshire, Chief Engineer of Structural Fibers, Inc., speak on "Reinforced Plastics" and Mr. John Gazdik, Chief Engineer of Akromold, Inc., speak on "Mold Design".

Officers for the coming year were announced as follows:

President—Henry Dutot, American Cyanamid Company

Vice President—Ed Haskins, Injection Molders Supply

Treasurer—Don Butler, Plastic Products Corporation

Secretary—Bill Parker, West Instrument Company

Western New England

Urethane Foams

MERLIN L. EVANS
(Plax Corporation)

The May meeting of the WNE Section was held May 3, 1961.

Ben Collins, General Manager of the Plastics Division for Nopco Chemical Company spoke on "Urethane Foam". His display of experimental work with Urethane foam was spectacular and challenging.

Sigmund Czarnecki, President and General Manager of Preferred Plastics Corporation, spoke on "Expanded Polystyrene and Its Applications."

ABOUT MEMBERS

Louis B. Allen

Louis B. Allen has been appointed manager, materials evaluation, materials laboratory for International Business Machines, Endicott, New York. He joined IBM in 1958 as an Associate Chemist.

Rex Brandt

The formation of Material Research, Warsaw, Indiana has been announced by **Rex Brandt**, president. Believed to be the only independent research and pilot plant in the country dealing exclusively in plastics, they do pilot plant work under contract. Mr. Brandt is also founder and president of Fiberfil Corporation which makes reinforced molding compounds.

A new company, Customs Materials Inc., Chelmsford, Mass., planning to manufacture isotorpoic dielectrics, radar loads and conductive plastics has been formed by **Ralph Mondano, Alfred I. Simon** and **Ralph Pratt,** all formerly with Raytheon Company. Plans are to expand into the fields of reinforced plastics and components for which they report manufacturing "know-how".

Lewis B. Connelly and **Joseph L. Reynolds** have been appointed to positions in sales at Eastman Chemical Products, Inc., plastics division. Mr. Connelly becomes district sales manager in New York City, and Mr. Reynolds heads the Dallas, Texas, plastics division, succeeding Mr. Connelly. Mr. Connelly's new post was held for the past 25 years by **William L. Searles** who is retiring.

Nixon-Baldwin Chemicals, Inc. has elected **Zenas Crocker** executive vice president. He has been a vice president since the formation of the company and its acquisition of Nixon Nitration Works early last year. A graduate of Massachusetts Institute of Technology with a B.S. in business and engineering administration, Mr. Crocker has helped develop numerous new thermoplastic sheetings.

Walter F. Oelman

The election of **Walter F. Oelman,** president, Standard Molding Corp., to the position of director and president of the Society of the Plastics Industry has been announced. Mr. Oelman holds an MBA from Harvard, 1932 and is an SPE Distinguished Member. He was SPE President in 1953.

H. J. Ried of Standard Insulation Co., has been elected vice-chairman of the Prepreg Division of the Society of the Plastics Industry Inc.

Frank M. Chapman

Frank M. Chapman has been appointed to the position of general manager of the Plastic and Rubber Products Co., Fluorocarbon Division. He is a chemistry graduate from the University of Vermont and was originally associated with Du Pont. Mr. Chapman who has published articles on fluorocarbons has most recently been assigned to development and marketing in the Midwest.

Willard M. Preston has recently been appointed to the position of eastern sales manager of Moplen Division of the Chemore Corp. and General Representative in the United States and Canada for Montecatini Soc. Gen. Mr. Preston has been active in various sales capacities with major plastics producers and fabricators since 1948.

C. J. Hussey, who has been recently named end use coordinator in the Sales Department of Koppers Co., was formerly the end use representative in the New York Sales office. A management engineering graduate of Rensselaer Polytechnic Institute, he joined Koppers in 1948 as a statistical analyst then becoming an operating engineer, shift foreman, technical representative and sales representative.

Islyn Thomas former president of the Newark Die Co., has recently established himself as a consultant to the plastics industry. Mr. Thomas, author of Injection Molding of Plastics, attended Columbia University and the University of Scranton, started at Consolidated Molded Products Corp. He later served as general manager of Ideal Novelty and Toy Co., and instructed plastics engineering at Brooklyn Polytechnic Institute. Mr. Thomas was National President of SPE in 1951.

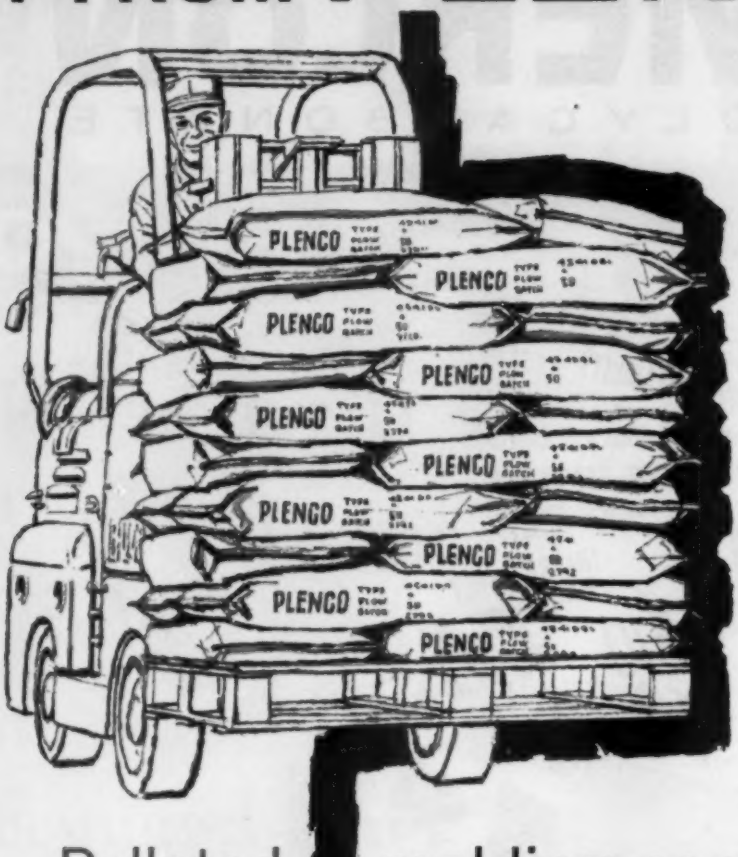
Milo H. Buzzee

Milo H. Buzzee has been promoted to the position of engineering manager of Tube Turns Plastics Inc. Mr. Buzzee formerly chief development engineer is a graduate of Northeastern University and was formerly associated with the Jackson and Church Co., as plastics department sales manager and with Du Pont where he worked as a chemical development engineer.

MERLON®

POLYCARBONATE

NEW FROM PLENCO



Palleted molding compounds for easier, low cost handling...

Do you know that PLENCO phenolic molding compounds are now available at no additional cost on expendable pallets? These pallets are 35" x 45" (holding 1500 lbs.), or 42" x 42" (holding 2000 lbs.), and you may specify the pallet size preferred by you.

Both are neat, uniform shipping units that can be safely stacked three high because all bags on each pallet are spot-bonded to each other, imparting unitized rigidity.

Palleted shipments reduce your direct labor handling cost. We have also added one other feature for easy inventory control and inventory status. We now stencil the material and batch numbers, color, flow, and customer's order number on the *sides* of the bag rather than the face. This makes identification easy and complete—with no need to climb on top of the load or remove a pallet to find out what's under it.

We don't expect a pat on the back for an idea as simple as this; but it does show that we are thinking in terms of your convenience when using PLENCO products.

a new convenience at no extra cost!

PLENCO PHENOLICS
FOR BETTER PLASTIC PRODUCTS

PLASTICS ENGINEERING COMPANY
Sheboygan, Wisconsin

Serving the plastics industry in the manufacture of high grade phenolic molding compounds, industrial resins and coating resins.

PLASTICS AROUND THE WORLD

This month's column has been made possible through the contribution of these abstracters:
Hans Mayer (Industries des Plastiques Modernes)
Leonard Buchoff (Materials in Design Engineering)
Alfred Alk (Materie Plastiche and Poliplasti)

France

INDUSTRIE DES PLASTIQUES MODERNES

APRIL 1961

The Gel Effect of Diamino and Hydroxyaminoacids on Omega-aminoacids and other Monomers which usually yield thermoplastic Polyamides.—Author: S. A. Szewcyk.

Tests have established that aminoacids with an imine function within the chain or omega-hydroxyacids with a third function within the chain will result in a thermosetting compound when mixed with other monomers, missing this third function like caprolactan, amino-undecanoid acid and others. This fact can be used to create thermosetting compounds of mixed polyamides and polyester-polyamides for film.

Italy

MATERIE PLASTICHE

MARCH 1961

"Dutral" Montecatini's New Synthetic Rubber—pp. 257-265

Dutral is an ethylene propylene copolymeric product developed by Professor Natta. Its lack of double bonds in the molecule makes it extremely resistant to oxygen aging at ambient and high temperatures, and gives it much lower temperature workability.

Influence of the Composition of Polyester Resins on the Optical Properties of Flat and Corrugated Laminates for Roofing.—pp 225-230

The article treats the phenomonon of clarity of image. A previous article (May, 1959) was concerned with total transmission of light through the laminate. Clarity is lost by passage of light rays as they pass from one substance (resin) to a dissimilar one (glass). If the index of refraction of both are equal, there is no change, and no scattering of light rays. The article examines current Italian polyethers.

Italy

POLIPLASTI

JAN.-FEB. 1961

I.U.P.A.C., Dusseldorf October 1959—pp. 2-43

The following papers, presented at the Conference are reproduced in this issue. "Reinforced Polyesters" by G. Tolley; "Standardization and Testing of Reinforced Polyester Resins" by B. Bossu and P. Dubois; "Principles of Polymer Stability" by H. Mark; "Recent Research on Macromolecules with Three-dimensional Networks and Instances of Reinforced Polyester Resins" by W. Funke; and "New Italian Uses of Glass Fiber Reinforced Polyester Resins in Different Fields" by M. Lenizini.

JAN.-FEB. 1961

Research on the Behavior of Plastics Reinforced With Glass Fibers Exposed to the Attack of Marine Vegetation and in Particular to Teredos.—pp. 49-50

This research is to determine how to protect submerged wooden structures in ports. A boat hull was coated in the usual fashion with polyester resin and was allowed to remain for nine months in an area noted for its favorable environment for marine growths. At the end of the test, the hull was removed and the organisms examined carefully. Growth was not retarded by the plastic coating, but the organisms were found to exhibit less adhesion than to wood and to have been unable to penetrate the resin. The teredos did not affect the surface.

MAR.-APR. 1961

The Construction of Reinforced Polyester Tanks—pp. 53-54

A complete description of one of the new storage vessels manufactured in Italy. Chemical and physical data are provided and compared to aluminum and steel.

United States

MATERIALS IN DESIGN ENGINEERING

FEBRUARY 1961

Large Plastics Moldings O.K.'d By Ultrasonic Inspection—pp. 13-16

Ultrasonic testing is used to detect location, size and orientation of voids, cracks, resin-rich, or resin starved areas in massive compression molded parts.

Chemical Process Equipment—pp. 116-118, 121-122

Glass-reinforced polyester laminates and rigid PVC are being widely used in stacks, ducts and tanks. Plastic pipe use has grown phenomenally. Hot spray vinyls and catalyst cured epoxies form protective liners in the process industry.

MAY 1961

What's Wrong with Data on Reinforced Plastics—pp. 121-125

The greatest single source of human error in testing reinforced plastics is preparation of the laminate. Strength and stiffness increase under high loading rates. Failures occur at the radius of tensile causing inaccuracies. Misinterpretations of Young's modulus data are caused by the sharp change that occurs in the range of 30%-50% of ultimate strength. Bearing type failures are seen in compressive tests if special test fixtures are not used. The flexural strength test for reinforced plastics is perhaps the most standardized, most used, and least meaningful of the mechanical tests.

Material Selection Awards—pp. 131-154

Awards were given in this year's competition by Viton-silicone rubber bladder for storing hydrogen peroxide; self-lubricating retainer rings of TFE fluorocarbon reinforced with glass microfibers and impregnated with molybdenum disulfide for 575°F bearings; a pump made from acetal molded parts; precision potentiometer whose conductor and insulator are made from diallyl phthalate; a contactor made of glass-polyester having increased arc resistance and strength; coils encapsulated by injection molding nylon; use of polypropylene to improve operation of heart-lung machine.

So that you can get the information you want in the shortest possible time, we suggest you write directly to the company address listed at the end of each new product item.

New Materials and Equipment

MATERIALS AND APPLICATIONS

Polyethers

Jefferson Chemical Company Inc., announces production of polyethers at Conroe, Texas. These products are raw materials for the formation of the various urethane foams. Inquire: *Dept. SPE,* **Jefferson Chemical Company Inc., 1121 Walker Ave., Houston 2, Texas.**

Blown Film Polyethylene

Koppers has available Dylan 2037, a polyethylene resin for extrusion into a clear glossy film of high strength. Reportedly extrudable at high speeds, it is easily colored, highly printable and easily sealed. Samples and Literature: *Dept. SPE,* **Polyethylene Product Manager, Plastics Division, Koppers Co. Inc., Koppers Building, Pittsburgh 19, Pa.**

Sub-Zero Urethane Foam

Nopco's Lockfoam H-602 is a new formulation for a urethane foam which is dimensionally stable at sub-zero temperatures and has a low overall density of two pounds per cubic foot. Useful for insulating items. Information and technical assistance: *Dept. SPE,* **Plastics Division, Nopco Chemical Co., North Arlington, New Jersey.**

Fire Retardant Rigid Foam

Hetrofoams are inherently fire retardant polyester urethane foams which do not have the structural weakness and poor aging qualities of the additive type of fire retardant foam. A hydroxyl resin and a semipolymer are combined and blown to produce a stable foam with good electrical and insulating properties. Information from: *Dept. SPE,* **Durez Plastics Division, Hooker Chemical Corporation, North Tonawanda, New York.**

New Gel-Coat

A new gel-coat for reinforced boat manufacturers is being offered by Plastic Molders Supply Co., which contains ultraviolet absorber, giving weatherability and color stability over a wide color range. *Dept. SPE,* **Plastic Molders Supply Co. Inc., 74 South Ave., Fanwood N.J.**

EQUIPMENT

One Piece Split Aluminum Cast Nozzle Band

Starcast Nozzle Band incorporates a tubular heater and a one piece split casting of a high temperature aluminum alloy. Plastic spillage has no effect. All bands are 1½ inches wide. The outside diameter has been standardized at 2½ and 3½ inches. They are available for 115 or 230 volts. *Dept. SPE,* **Glenn Electric Heater Corporation, 372 Jellif Avenue, Newark, N. J.**

Low Cost Vacuum Conveying System

A simple, efficient and low cost system capable of unloading up to 8000 pounds of material per hour and distances up to 300 feet has been developed. Automatic vacuum feed shut off and reverse cycles are features of this unit. *Dept. SPE,* **Whitlock Associates, Inc., 21655 Coolidge Hwy., Oak Park 37, Michigan.**

Single Screw Injection Molder

An improvement of the Swiss Neomat SM60/40 has been introduced to America. A faster single screw machine it is suited for molding rigid PVC, nylons, acrylics etc. Featuring screw plasticizing and injection for shots up to 31/2 ounces, it attains high production speed and can be controlled by semi or fully automatic controls. Information, *Dept. SPE,* **Husky Manufacturing and Tool Works (Ontario) Limited, 200 Bentworth Ave., Toronto 19, Ontario.**

Automatic Plastic Injection Molding Machine

A fully automatic, hydraulically operated injection molding machine capable of producing items of up to 1½" o.d. vinyl is now available. Called "Auto-Hornet", it includes converging bore injection assembly with pyrometer control of the three cylinder heaters and has a maximum dry timer cycle of 500 per hour. Write *Dept. SPE,* **Newbury Industries, Inc., Newbury, Ohio.**

Screw Plasticizer

A new line of screw plasticizers for attachment to standard injection molding machines is being offered. Of Xaloy steels, the melt capacity is rated at 90-250-500 pounds per hour. For specifications, write *Dept. SPE,* **Waldron-Hartig Division, Midland Ross Corporation, Box 791, New Brunswick, N. J.**

MANUFACTURERS' LITERATURE

Hydraulic Presses

French Oil Mill Machinery has a bulletin available on various presses. Illustrations, specifications are given along with some engineering tables. *Dept. SPE,* **The French Oil Machinery Co., Hydraulic Press Division, Piqua, Ohio.**

Marking Literature

The Acromark Co. has available a substantial amount of literature on their many marking and stamping machines. Catalog 54HS offers a detailed covering of hot stamping machinery, tools and accessories. *Dept. SPE,* **The Acromark Co., 365 Morrell St., Elizabeth 4, N. J.**

Storage Guide for Industrial Solvents

U.S.I.'s bulk storage guide covers government regulations tank design, piping, valves, measuring devices, electrical grounding procedures vents, etc. Drawings are included. *Dept. SPE,* **Technical Literature Dept., U.S. Industrial Chemicals Co., 99 Park Ave., N. Y. 16, N. Y.**

Laminate Data

Brochures on Synthane's copper-clad and new high temperature laminates are available. Copper clad laminates are used in printed or etched circuits and the high temperature laminates find applications above 1000°F for short exposures and at 500°F for longer periods. *Dept. SPE,* **Synthane Corp., Oaks, Pa.**

Electric Motor Selection

A 16-page bulletin which describes the complete line of new Reliance motors is available. Motors are from 1 to 1000 H.P. *Dept. SPE,* **Reliance Engineering Co., Cleveland 17, Ohio.**

Employment & Service Guide

POSITIONS OPEN

EXTRUDER—THERMO PLASTICS

Position open, man, experienced extrusions and related machinery. Excellent opportunity, growth potential, qualified man. Interviews confidential. H. G. Jacobs Mfg. Co., Paterson, N. J. AR 4-7640.

ENGINEER— MOLD DESIGN AND MANUFACTURING

For transfer and compression molding of small high precision parts for the Electronic industry.

Work on the drafting board, follow up pilot runs of new molds, do quality control and initiate corrective action.

Min. of 5 years experience. Newark, N. J. area.

Reply to Box No. 247, SPE Journal.

CHALLENGE—OPPORTUNITY

For the Right Man

Specifications: College and industrial trained professional man with experience in plastic materials and their useful application, supplemented by general familiarity with plastic fabrication techniques.

Leadership quality and an ability to work easily and effectively with other highly skilled professionals are important prerequisites.

If you think you're pretty good, and can prove it, apply in writing giving complete qualifications and references to M. H. Nickerson

Arthur D. Little, Inc.
130 No. Franklin St.
Chicago 6, Illinois
Midwest Division

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

PLASTICS DEVELOPMENT ENGINEER

We have an attractive opening in our New Product Development Dept. for an engineer or chemist to work on fabrication techniques for new thermoplastics. B.S. minimum, 3-10 years broad experience in fabrication of plastics, especially extrusion. Send resume in confidence to Dr. David M. Clark, Director of Technical Recruiting, W. R. Grace & Co., Research Division, Clarksville, Md.

PLASTICS ENGINEER

New position with expanding southern California pharmaceutical laboratory. Project assignments in formulation of polyvinyl chloride for extrusion and plastisols. Knowledge of processes for injection molding and dipping desirable. B. S. degree in engineering or chemistry required. Professional position offers excellent salary commensurate with experience and opportunity to apply technical training to development of life-giving hospital products.

Please write to:
Daniel H. Stark
Don Baxter, Inc.
1015 Grandview Avenue
Glendale 1, California

SALES ENGINEER

We need a young man with ideas and product development ability to represent a *young, vigorous, progressive* injection molder that has succeeded on ideas.

We have complete experimental and mold making facilities on the premises. We operate completely automatic molding equipment, located in a northern suburb of New York City.

Excellent opportunity for a man with drive. Salary, incentives, benefits.

Reply, Box No. 244, SPE JOURNAL.

POSITIONS WANTED

MANUFACTURING EXECUTIVE

Former Vice-President Manufacturing. Production, Quality, Tool and Product Design. Cost Reduction. Sales Engineering. Desires Position Manufacturing, Design & Sales Engineering. Experience: Injection, Extrusion, Tube Blowing, Casting and Polyester Laminates. Age 42. Experience 22 years. Presently Employed. Will Relocate. Reply Box No. 229, SPE JOURNAL.

CLASSIFIED INFORMATION AND RATES

SPE members in good standing are entitled to a total of three no-charge "Positions Wanted" advertisements within any 12-month period, each ad (not to exceed 50 words) should include training, experience, location desired; headline (not to exceed 3 words) must state job description. Additional words will be charged @ 25¢. *Do not* submit resumes: none are kept on file.

Last day for inserting all classified ads is the first day of the month preceding date of publication, except for display size ads which close on the 15th of month preceding issue date.

"Positions Open" and "Positions Wanted" —$12.50 per column inch, 2¼ inches wide. (35 characters per line; 7 lines per inch).

Minimum charge: $12.50. Pre-publication contact, known as the "Availability File"—$5 service charge on "Positions Open"; no charge to SPE members. *See adjacent box for a description of how it works.* "Products and Services" and "Business Opportunities" —$20.00 per inch. Minimum charge: $20.00.

All ads include one bold face caption line. Additional caption lines @ $2.50 extra per line. Boxed ads (4-sided rule)—$3.00 extra. Agency commission allowed only on ads 5 inches or more in depth. Display ads of 1/16 page or more are charged at regular advertising space rates. No ¼ page or vertical ½ page ads published within Employment Service Guide section. Typesetting (non-commissionable) will be charged at cost.

HOW OUR "AVAILABILITY FILE" WORKS

If you are a company, or an SPE member who will be advertising in SPE JOURNAL, you can receive copies of those classified ads of potential interest to you *before* they are actually published in the Journal, provided that these advertisers have also indicated their interest in the same procedure. This pre-publication contact is what we call our "Availability File". All you have to do to participate is to sign the return postcard we send you upon receipt of your advertising insertion. When your card is returned, the ads are sent to you as they come in, up to publication date.

PLASTICS, RUBBER IN ELECTRONICS

17 years with government agency in military electromechanical applications, material specifications. B. Ch. E. 1942. Collaborate with electronic, mechanical engineers in prototype development. Laboratory: 10 years supervisory experience in mold design; compression, transfer, injection molding; rubber compounding, some resin-filler blending; testing. Age 47, family. Minimum salary $11,500. Resume. Box No. 246, SPE JOURNAL.

PLASTICS—CHEMICALS ADMINISTRATOR

Continuous record of accomplishments in research, commercialization, administration. Diversified experience in thermoplastic and thermoset adhesives, coatings, foams, molding, potting, casting compounds. Could make substantial contribution. Box No. 245, SPE JOURNAL.

PLASTICS ENGINEER

Graduate Chemical Engineer, 38; 8 years varied experience in epoxies, silicones and urethanes for electrical and high temperature missile applications. Experience includes technical programming for materials and processes, proposal preparation, and some supervisory experience. Married, with 3 children. Willing to relocate. Resume available. Box No. 241, SPE JOURNAL.

PLANT MANAGER

Nine years experience in transfer, compression, injection and extrusion molding. Knowledge of all phases of design, planning, quoting, production, finishing. Desires plant management or general management position. Resume on request Will take any domestic or foreign location. Box No. 239, SPE JOURNAL.

CHEMIST

Experience from research through manufacturing in printed circuits, anodizing and 100% solid alkyd and epoxy industrial coating systems. I am interested in technical service, research and/or product development. Relocation out of New York City desired. Detailed resume on request. Box No. 240, SPE JOURNAL.

SALES ENGINEER

BSME, PE, available in several weeks to one or more employers on part time or full time basis. Twelve years of broad experience in manufacturing. Good knowledge and understanding of the problems in industry, the orientation and motivation of its key men. Has the perception of an engineer, the dedication of a manager. Able to resolve facts, cut through confusion, eliminate irrelevant intangibles and focalize on your product or service in its right place in the customer's operation. Prefers to locate in N. J. Box No. 255, SPE JOURNAL.

Advertisers' Index

American Cyanamid Co.—Plastics & Resins Div. 631
Argus Chemical Corp. 672
Barber-Colman Co.—Wheelco Industrial Instruments Div. 636
The Black-Clawson Co. 630
Crucible Steel Co. of America 657
Detroit Mold Engineering Co. 660
Dow Chemical Co.—Molding Materials 694
Dow Corning Corp. 628
Emery Industries, Inc. (Organic) 688, 689
Enjay Chemical Co., Div. Humble Oil & Refining Co.
Chemicals 627
Plastics ..... Cover 3
Farrel-Birmingham Co., Inc. 687
General Color Co., Div. H. Kohnstamm & Co., Inc. 639
General Electric Co.—Chemical Materials Dept. 640
Gering Plastics, Inc., Div. Studebaker-Packard Corp. ..... Cover 4
Goodrich-Gulf Chemicals, Inc. 658, 659
Harchem Div., Wallace & Tiernan, Inc. 632
Hercules Powder Co. 638
H. Kohnstamm & Co., Inc., General Color Co., Div. 639
Improved Machinery Inc. 651
Injection Molders Supply Co. 663
Lucidol Div., Wallace & Tiernan, Inc. 633
Mobay Products Co. 699
National Distillers & Chemicals Corp., U. S. Industrial Chemicals Co., Div. 643, 644
National Lead Co. 664
Package Machinery Co. —Reed-Prentice Div. 626
Chas. Pfizer & Co.—Commercial Development Dept. 623
Pittsburgh Chemical Co., Industrial Chemicals Div. 691
Plastics Engineering Co. 700
Prodex Corp. 652
Reed-Prentice Div., Package Machinery Co. 626
John Royle & Sons ..... Cover 2
The Simco Co. 656
Spencer Chemical Co. 641
Studebaker-Packard Corp., Gering Plastics, Inc. ..... Cover 4
Union Carbide Chemicals Co., Div. Union Carbide Corp. 696
Union Carbide Plastics Co., Div. Union Carbide Corp. 634, 635
U. S. Industrial Chemicals Co., Div. of National Distillers & Chemical Corp. 643, 644
West Instrument Corp. 624
Wallace & Tiernan, Inc.
Harchem Div. 632
Lucidol Div. 633

PRODUCTS & SERVICES

MOLDS

Injection compression transfer, quality molds, good delivery, competitive prices. Tested before delivery, laid down in your plant. Steel Dies & Moulds Ltd., 43 Raleigh Ave., Toronto, Canada. PH. AM 1-7092

INJECTION • BLOWING
COMPRESSION • TRANSFERS

MOLDS

Quick Delivery, Cheapest Prices

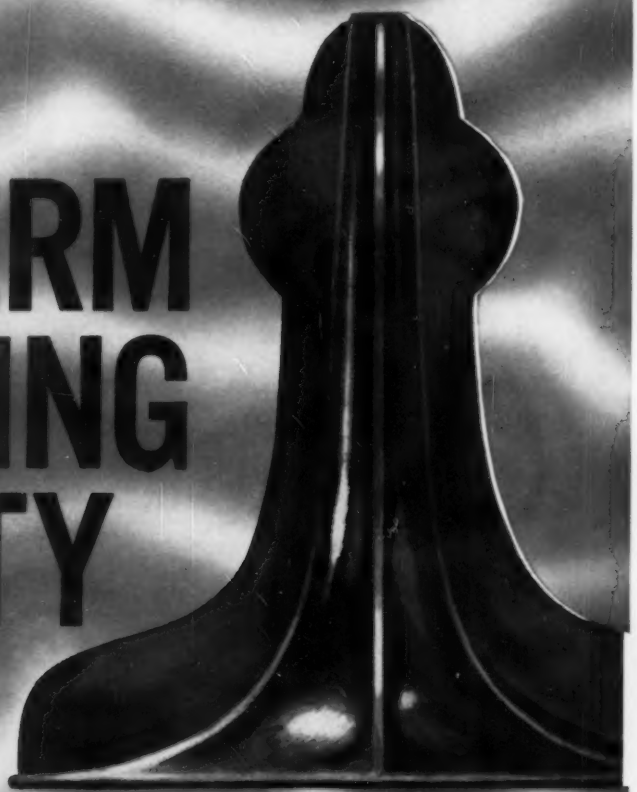
DANISH MOULD ENGINEERING

Osterbrogade 54D

phone **TRIA 3100** • *cable* **DANIMOLD**
COPENHAGEN, DENMARK

What's News in Plastics...

LONG TERM HEAT AGING STABILITY



Washing Machine Parts

TV Backings

Vaporizers

Radio Cabinets

Yours with new Escon® 125 molding grade polypropylene!

Household appliances, radio cabinets and TV backings take full advantage of the remarkable properties of Escon 125 polypropylene. This outstanding new grade is designed to maximize performance for long periods at high temperatures. Exceptional performance is achieved through a special LTHA (Long Term Heat Aging) stabilization system developed by Enjay research affiliates.

Escon 125 offers oxidative stability that, in carefully conducted laboratory tests against other commercially available grades of polypropylene designed for this type of service, outperformed all others tested. Specimens of Escon 125 withstood almost three months of oxidative aging at 300°F; specimens exposed to 250°F have shown no signs of failure after seven months.

Melt index is 5.5 at 230°C. No changes are required in equipment, processing conditions or coloring techniques from those used with general purpose molding grades. For test samples and typical properties of new Escon 125, write to Enjay, 15 West 51st Street, New York 19, New York.

EXCITING NEW PRODUCTS THROUGH PETRO-CHEMISTRY

ENJAY CHEMICAL COMPANY

A DIVISION OF HUMBLE OIL & REFINING COMPANY

ENJAY

PLASTICS

ONE
bY ONe
bY
ONE

Gering Quality Molding Compounds Answer Your Demands...

• for the fullest color range with uniformity from batch to batch • for exact physical properties that improve production by fewer rejects and faster molding cycles • for money-saving, quality-formulated *polyethylene, polypropylene, vinyl, polystyrene, styrene copolymers, acetate, nylon, acrylic and butyrate.*

GERING

PLASTICS

Division of STUDEBAKER-PACKARD CORP., Kenilworth, N. J. • Cable Address: GERING, Kenilworth, N. J. Teletypewriter: TWX Cranford, N. J. 137 • Sales Offices: 5143 W. Diversey Ave., Chicago 39, Ill. • 1115 Larchwood Rd., Mansfield, Ohio • 103 Holden St., Holden, Mass. • 1855 Industrial St., Los Angeles, Calif. 426 Los Niños Way, Los Altos, Calif. • P.O. Box 963, Minneapolis 40, Minn. • 2141 Sunnyside Pl., Sarasota, Fla.